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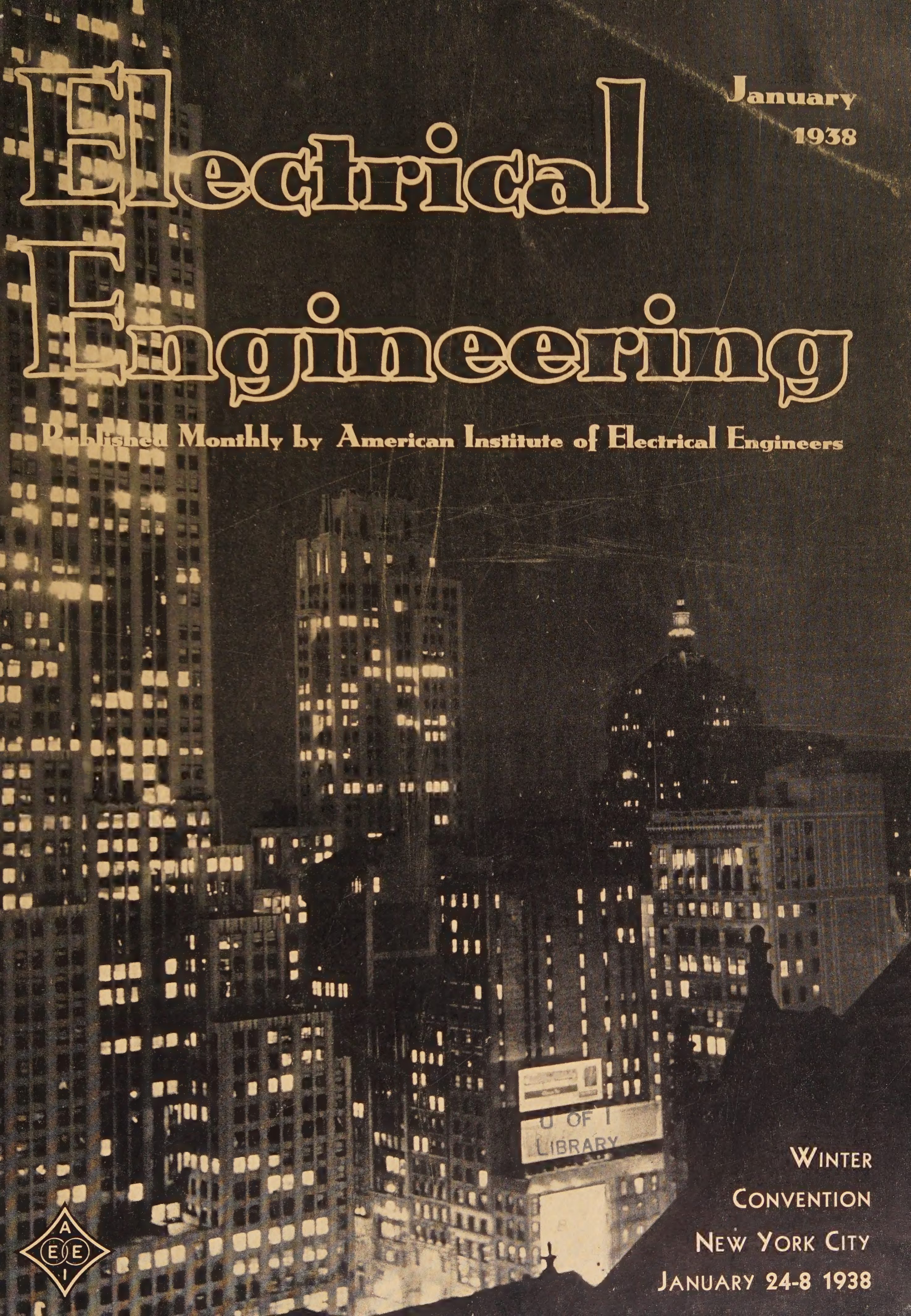

Winter
Convention
New York City
January 24-8 1938

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To Measure—LIGHT ELECTRICALLY

LIGHT long resisted the efforts of scientists to measure it without dependance on the visual ability of the human eye.

For years, every equipment—from the simple Bunsen photometer to the intricate integrating sphere—depended for its operation on visual ability to distinguish between various degrees of illumination.

Then . . . about the year 1918 . . . scientists began to experiment with the photoelectric tube, i.e., the "electric eye," to replace the human eye in these measurements. From then on, progress was steady; today, every illuminating laboratory uses the photoelectric-tube method. But all such equipments—while highly accurate—are complicated and are limited to the laboratory.

Finally—in a tiny, compact device, small enough to hold in the palm of your hand, G-E engineers have developed a convenient, low-cost instrument for measuring illumination. It is completely self-contained and so easy to use that anyone—even a child—can measure light with it.

Not only in this field — but in many others — G-E measurements engineers made noteworthy contributions. Today, there are G-E instruments to measure almost everything from color hue, flash of lightning, or the slightest sound, to the usual electrical values of current and voltage. Remember General Electric Company, Schenectady, New York as. . . . .

HEADQUARTERS FOR ELECTRICAL MEASUREMENT

GENERAL ELECTRIC

430-83

Electrical Engineering

Registered U. S. Patent Office

for January 1938—

Transactions Section *(Follows EE page 48)*

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The Cover

Night view looking northeast from the roof of the Engineering Societies Building in New York City, headquarters for the Institute's forthcoming winter convention

Photo by Floyd A. Lewis (A'31, M'35)

High Lights

New Publication Procedure. This is the first issue of ELECTRICAL ENGINEERING to be published in accordance with the new developments in publication policy announced in the November 1937 issue, page 1409. Under the new provisions, this and succeeding issues will consist of two principal parts. For example, in this issue the first 48 pages contain articles of general interest and news of Institute and related activities, and the following section of 60 pages contains papers preprinted from the 1938 volume of the TRANSACTIONS. Following a necessary transition period, all discussions published will be correlated with their respective papers. Another feature of the new plan is the provision of "advance copies" of papers approved by the technical program committee for presentation at national conventions and District meetings; an order form is included in the advertising section of this issue.

Electric Passenger Vehicles. The past few years have brought about great changes in vehicles and equipment for public surface transit in urban centers. Development of the Presidents' Conference Committee street car, new and greatly improved trolley coaches, and gas- and Diesel-electric busses and the introduction of the "all-service" vehicle have brought about marked changes and improvements in electric propulsion equipment (*Transactions pages 50–6*). Economically, electric trolley coaches are not adaptable to public transportation in all urban centers, for each city has its own peculiar transportation problems. Some of the economic and operating features of electric trolley coaches have been outlined, with the aim of indicating the type of community in which the electric vehicle is most suitable (*Transactions pages 57–60*).

Winter Convention. At the "general" session of the AIEE 1938 winter convention, which will be held in New York, N. Y., January 24–28, a noted economist will speak on a subject of importance to engineers (*page 36*). Other winter-convention attractions announced in this issue include: presentation of the 1937 Edison Medal to a past-president of the Institute; the annual smoker and dinner-dance; an interesting variety of inspection trips; and a post-convention cruise to Bermuda. Changes have been made in five technical sessions, and programs of several technical conferences have been announced (*pages 33–5*).

Correlation of Sphere-Gap Data. Sphere gaps, although widely used for measuring high voltages, are not absolute standards; consequently, any improvement in the measurement of spark-over voltages by means of the sphere gap must come from frequent correlations of data obtained by independent observers. A new correlation presents spark-over curves for spacing-to-diameter ratio; suggestions for a spark-over voltage chart covering the entire useful range of sphere sizes, spacings, and air densities; and new air-density correction factors (*Transactions pages 45–9*).

Tensor Analysis. A new game, called "hunting the tensor" is introduced for the first time in this issue. This game has been designed with the specific intent of disturbing the electrical engineer's latent curiosity about the reputably abstruse subject of tensor analysis. The hunt consists of three parts. The tensor specimen is caught in this issue, but the mounting and cataloguing of the specimen must remain for a subsequent installment (*pages 3–9*).

Thyratron Motors. The search for a simple variable-speed a-c motor has extended over many years, yet no generally known device has been thoroughly satisfactory. Many types of a-c drive are in use today and many more have been designed and discarded or never applied. The thyratron motor, devised within the last few years, or some similar electronic device, may provide the ultimate solution to the problem (*Transactions pages 19–24*).

Studies of Living Tissue. An extension of a previous paper on electrical studies of living tissue shows that human and frog tissues behave electrically as a simple circuit consisting of one capacitor and one or more resistors. The correlation between tissue response and the voltage distribution in live tissue has been determined and is described on the basis of the voltage distribution in the equivalent circuit (*Transactions pages 1–4*).

Carrier-Pilot Relay System. A paper in this issue outlines some of the reasons for the use of pilot-relay equipment and describes a new high-speed distance type of carrier-pilot relay system in which the desirable high-speed and back-up characteristics of the step type of distance protection are combined with the simultaneous tripping characteristics of a pilot circuit (*Transactions pages 5–10*).

Corona Voltages in Transformers. In insulation tests of oil-immersed transformers, insulation deterioration has been found to be caused by corona or local discharges in the oil and over solid insulation surfaces. Results of a series of tests show that the impulse voltage at which corona appears is about 2.2 times the 60-cycle voltage at which it appears (*Transactions pages 34–6*).

Prizes for Papers. AIEE national and District prizes for initial and Branch papers to be awarded during 1938, will be accompanied by cash awards (*page 37*).

Resistance Welding. A subcommittee report describes some of the recent advances in controlling time, pressure, and current in resistance-welding processes and some of the improvements in welding apparatus. Electric-welding engineers are attempting to establish quantitative, scientific methods of resistance welding, instead of the outmoded rule-of-thumb methods (*Transactions pages 37–8*).

Petersen Coils. Until recently, Petersen coils, although widely used in Europe in protective grounding practice, have been little used in the United States. Electric service may be improved by the use of properly designed and applied Petersen coils (*Transactions pages 11–18*).

Carrier Telephone System. In a new single-channel carrier telephone system, opposite sidebands of the same carrier frequency are used for opposite directions of transmission. The upper sideband is used in one direction and the lower sideband in the other, the carrier being suppressed (*Transactions pages 25–33*).

Temperature Limits. Oil-immersed neutral-grounding transformers and reactors should not exceed safe temperature limits during faults that may last for several minutes; temperatures for various fault durations that will produce the same aging of insulation as is produced by the present standard of 160 degrees centigrade for a fault period of one minute may be found by calculation (*Transactions pages 39–44*).

Electrons. Devices depending for their operation upon those small negative particles called electrons constantly are increasing in number. What the electron is, how it constitutes electricity, and how it may be used are told in a simple way in an article intended to aid those who may not be familiar with recent theories in this subject (*pages 26–32*).

Interconnected Systems. An engineer widely recognized as an authority on interconnection problems describes in this issue some typical operating and economic advantages of interconnection, based upon experience with a co-ordinated system extending over a large area east of the Mississippi River (*pages 16–25*).

Electrified Railroad System. Design and operating details of the extension of the Pennsylvania Railroad's electrified system to Harrisburg, Pa., now nearing completion, are described in an article in this issue (*pages 10–15*).

Letters to the Editor. Discussions of the following topics are included in this month's "Letters" section: registration of engineers, tensor analysis, capacitor motors, and graphical solution of impedances (*pages 41–3*).

Statements and opinions given in articles and papers appearing in ELECTRICAL ENGINEERING are the expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on all controversial matters. ¶ Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶ Address changes must be received by the fifteenth of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index;* abstracted monthly by *Science Abstracts* (London). Number of copies this issue—21,800.

What Is Tensor Analysis?

By BANESH HOFFMANN

Although a powerful analytical engineering tool, tensor analysis has been supposed by many to be an abstract toy used only by the mathematician and the theoretical physicist. This article, written by a mathematician, is intended to present the rudiments of the subject, and to point the way toward further study and a working knowledge of tensors in engineering. Readers who feel that mathematical subjects cannot be exposed in an entertaining—or even amusing—fashion may find in this article something of a surprise.

THE TENSOR'S reputation for performing prodigious feats in the more intricate realms of mathematics and physics unfortunately has given to many the impression that the understanding of tensor analysis is within the powers of only a few highly trained specialists.

Actually there is very little difficulty in tensor analysis, and its main ideas can be easily understood by anyone who has been able to grasp the essentials of, say, the differential calculus. The greatest difficulty in the study of the tensor calculus is the feeling of hopelessness its remarkable reputation inspires in the would-be student; and once this feeling is overcome the tensor stands revealed as a quite simple concept, which has in fact often been seen before, in various guises, in elementary mathematics.

True, the tensor is a being of considerable power. But it has been so thoroughly trained by the world's greatest trainers of unruly invariants that it is rapidly becoming a favorite domestic pet of infant mathematicians, and what I want to do in this article is to tell enough about its habits so that the reader will begin to feel a warm friendship toward it. No attempt is made to be mathematically complete; there is no space for that here. Nor is this article to be regarded in any sense as a textbook on elementary tensor analysis. Instead, it should be viewed as a supplement to existing textbooks on the subject, and as a general survey and sight-seeing tour of the ground they cover so much more adequately.

This article falls naturally into three parts. The first treats the fundamental ideas of tensor analysis so far as algebraic properties are concerned. This will serve to bring out the essential nature of the tensor and will pave the way for the second part, in which differential properties of the tensor are discussed. The third part is concerned with some of the applications of tensor analysis in mathematics and physics and illustrates the less specific discussion of the first two parts.

Equations are numbered so as to indicate the part to which they belong. Thus equations 1.9 and 1.13 belong to part I, with 1.13 later than 1.9, while equations 2.3 and 3.5 belong, respectively, to parts II and II.

Part I—Algebraic Properties

We are going to indulge in that well-known, and justly famous, indoor sport of hunting the tensor. We want to do this as simply as possible, but the one-dimensional tensor looks rather stupid when caught and bears no superficial resemblance whatever to its multidimensional relatives—think of a one-dimensional vector, for instance—so we must hold our hunt in two dimensions.

What shall be our hunting ground? Well, consider two points P, Q in a plane, their Cartesian co-ordinates being (x, y) and $(x + dx, y + dy)$ respectively. Their distance apart, which we call ds, is given by the well-known Pythagorean formula

$$(ds)^2 = (dx)^2 + (dy)^2 \tag{1.1}$$

Lurking in this apparently guileless equation are as many as four different varieties of tensor; a scalar, a vector, a second-rank tensor, and another vector of a type different from the first. Can there be any question that this is going to be our hunting ground?

We must not expect the hunt to be easy, for the more elaborate tensors are masters of the art of concealment and have developed a system of protective coloring of such efficacy that it enabled them to remain hidden from the searching eyes of mathematicians for centuries. So difficult are they to see, indeed, that once they have been caught it is often necessary to fasten an indelible label on their backs or they will vanish from sight again. We shall have occasion to use this technique during the present hunt.

Since we know so very little about tensors as yet, I shall bring along some reference books and we shall call a halt whenever we are in doubt, to find out what information they have to help us.

The essence of all detection being method, let us be systematic. Our first step is to label everything in sight with great care, and in such a way that we can file away all our data in an immediately accessible manner. Accordingly, we methodically give to the co-ordinates x, y the numbers 1, 2. But to remind ourselves that they are still co-ordinates we also use an x. Thus

$$x \rightarrow x^1,\ y \rightarrow x^2 \tag{1.2}$$

Written especially for ELECTRICAL ENGINEERING, this is the first of three parts of an article presented because of the widespread interest in the subject among Institute members. Parts II and III will appear in an early issue.

BANESH HOFFMANN is an instructor in mathematics at Queens College, Flushing, N. Y. Doctor Hoffmann was born in England in 1906. After receiving his early education at St. Paul's School, London, he studied mathematics at Oxford University, graduating in 1929 with first-class honors. He then came to the United States to be assistant to Professor O. Veblen at Princeton University, where he subsequently received the degree of doctor of philosophy. Following a period as research associate at the University of Rochester, he returned to Princeton as a member of the Institute for Advanced Study to work with Einstein, Infeld, and Veblen. Doctor Hoffmann is the author of more than 20 research papers, mainly in the field of relativity theory. In recent years he has presented papers on tensor analysis at several AIEE meetings.

Is this too pedantic? After all, we must look ahead, and what could we do in a couple of hundred thousand dimensions? We couldn't give different letters to the different co-ordinates and there seems no way of avoiding the idea of numbering them instead. In n dimensions the co-ordinates are denoted by $x^1, x^2, \ldots, x^n$.

As to filing away our data, we certainly must put all the co-ordinates in the same folder. We label the folder x^a and put into it x^1 and x^2; in n dimensions, $x^1, x^2, \ldots, x^n$.

Forget about this n-dimensional business for the present. When we have found out all about two-dimensional tensors we have only to say, "Presto! $a, b, \ldots$ to go from 1 to n instead of from 1 to 2," and we shall at once find ourselves in n dimensions.

So far, then, we have the notation

$$x^a = (x^1, x^2) = (x, y) \tag{1.3}$$

implying also

$$dx^a = (dx^1, dx^2) = (dx, dy) \tag{1.4}$$

The almost continual mention of co-ordinate systems in reference books shows that they must be very intimately related to our problem. We had better investigate them. In this part we shall be concerned only with co-ordinate systems in which the co-ordinate lines are straight. The most general transformation of co-ordinates which preserves their straightness is of the form

$$\bar{x} = px + qy, \bar{y} = rx + sy \tag{1.5}$$

where $(\bar{x}, \bar{y})$ are the new co-ordinates and p, q, r, s are constants.

The notation given in equation 1.3 does not seem to offer any advantage. But let us extend the idea a little. Let us put all the constants p, q, r, s into the same folder and label it C^a_b, where the suffixes a, b range over 1, 2 independently and

$$\begin{array}{c|c} C^1_1 & C^1_2 \\ \hline C^2_1 & C^2_2 \end{array} = \begin{array}{c|c} p & q \\ \hline r & s \end{array} \tag{1.6}$$

We can now write equation 1.5 compactly in the form

$$\bar{x}^a = \sum_{b=1,2} C^a_b\, x^b \tag{1.7}$$

Long association with such obedient slaves as tensors produces extraordinary exhibitions of laziness; and Einstein, noting that a summation sign occurred only when a suffix appeared twice, decided to omit the summation signs entirely and make the convention that repeated suffixes are automatically to be summed over their whole range of values. This is called the *summation convention** and allows us to write equation 1.7 in the form

$$\bar{x}^a = C^a_b\, x^b \tag{1.8}$$

We shall use this convention consistently throughout.

Let us fortify ourselves by finding the definition of a tensor, and then we can start out on the hunt. The definition is somewhat shocking. It seems to consist entirely of abstract nonsense. But let us note a slightly simplified version for the present and see if we cannot understand it better after we have caught a few representative tensors and studied their habits at first hand. The definition makes use of the notion of an inverse transformation and we must look at this before we can talk about tensors in general.

Suppose that we transform from co-ordinates x^a to co-ordinates $\bar{x}^a$ by means of equation 1.8 and from $\bar{x}^a$ to $\bar{\bar{x}}^a$ by means of

$$\bar{\bar{x}}^a = c^a_b\, \bar{x}^b \tag{1.9}$$

Then if, when we get to the co-ordinates $\bar{\bar{x}}^a$, we find ourselves back in the co-ordinate system from which we started, namely x^a, we call transformation 1.9 the *inverse* of transformation 1.8. If we work out the relationship between $\bar{\bar{x}}^a$ and x^a obtained from equations 1.8 and 1.9 we find

$$\bar{\bar{x}}^a = C^a_b\, c^b_c\, x^c \tag{1.10}$$

which the reader can verify for himself by writing the various equations in full. Remember the summation convention applies twice in equation 1.10. If equations 1.8 and 1.9 are inverse transformations,

$$\bar{\bar{x}}^a = x^a$$

which may be written

$$\bar{\bar{x}}^a = \delta^a_c\, x^c \tag{1.11}$$

where

$$\delta^a_c = \begin{array}{c|c} \delta^1_1 & \delta^1_2 \\ \hline \delta^2_1 & \delta^2_2 \end{array} = \begin{array}{c|c} 1 & 0 \\ \hline 0 & 1 \end{array} \tag{1.12}$$

So the condition that equations 1.8 and 1.9 be inverse is that

$$c^a_b\, C^b_c = \delta^a_c \tag{1.13}$$

If the reader will write all these equations in full he will see exactly what they signify and will also obtain a clear idea of the useful habit of the quantity δ^a_c of changing suffixes, as $x^a = \delta^a_c\, x^c$. Since δ^a_c is always turning up and doing useful work it has earned the title *Kronecker delta*, in honor of the famous mathematician Kronecker, who apparently did not invent it.

We can now look at the definition of a tensor, but for goodness sake let us not try to understand it just yet. We shall merely store it away for reference. According to our textbooks a tensor seems to be something or other having 2^r components in each co-ordinate system —n^r in n dimensions. Here r is some integer, $0,1,2,3,\ldots$, depending on the type of tensor. If these components are denoted by the symbol $T^{ab\ldots}_{cd\ldots}$, the dots denoting further suffixes, then whenever the co-ordinates transform according to equation 1.8 the components of the tensor transform according to the law

$$\bar{T}^{pq\ldots}_{rs\ldots} = T^{ab\ldots}_{cd\ldots}\, C^p_a\, C^q_b \ldots\, c^c_r\, c^d_s \ldots \tag{1.14}$$

Starting the Hunt for the Tensor

We start the hunt by looking for the scalar in equation 1.1. This happens to be very easy. The reference books point out that a scalar is merely a tensor with no suffixes and thus with only one component in each co-ordinate

* For us to call it an exhibition of laziness is like the pot calling the kettle black. Do we not ourselves habitually omit the usual × sign for multiplication?

system. What is its law of transformation? If we study equation 1.14 carefully we see that a scalar must transform according to the law

$$\bar{T} = T \tag{1.15}$$

This looks trivial, but consider how important such an entity is in everyday life. We see that a scalar is something which can be measured by one number and which has the same value for every co-ordinate system. Practically everything we can think of in mathematics and physics seems to be a scalar; for example, the number of vertices of a geometrical figure, the sum of its angles, the length of a line, the magnitude of a force, the volume of a lump of rock. We are almost tempted to think that everything is expressible by means of scalars, but we shall later find many things that are not scalars.

Where is the scalar in equation 1.1? Obviously it is ds, since this quantity is the length of the line PQ and, however much we fool around with the co-ordinate system, the actual points P and Q, and therefore also the value of ds, will not change.

That was simple. But before we start looking for the vector let us remark that if the left hand side of equation 1.1 is a scalar, the right hand side must be too. This is going to be of real interest later.

Now for the vector. The reference books all seem to agree that a vector is a tensor with only one suffix. That is all very well, but we happen to know a vector is nothing of the sort. It is something having magnitude and direction. Why do the books try to confuse us by using the word in a different sense?

The books all say the same thing. Perhaps there is some sense to it after all. Certainly the definition of a vector as something having magnitude and direction

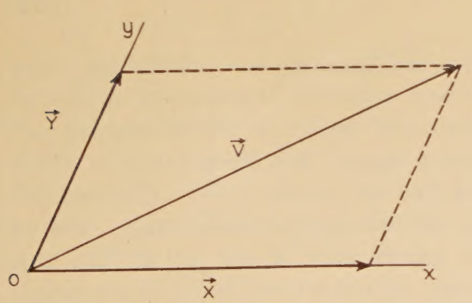


Figure 1. Sketch demonstrating the parallelogram law of addition as applied to vectors

cannot be entirely correct. It includes an extraordinary assortment of miscellaneous objects which are anything but vectors; for example, archers' arrows, compass needles and even, with a little stretching, symphony orchestras!

What is it, then, that distinguishes between genuine vectors and flag poles, stars, and similar objects undoubtedly having magnitude and direction? It is the parallelogram law of addition. Two genuine vectors $\boldsymbol{X}$, $\boldsymbol{Y}$ may be added to form the vector $\boldsymbol{V}$ as shown in figure 1. Evidently archers' arrows, flag poles, and similar things do not behave in this way. They are therefore not vectors.

This vector law of addition is important. It shows that vectors have components. For the vector $\boldsymbol{V}$ can be replaced by the sum of the vectors $\boldsymbol{X}$, $\boldsymbol{Y}$, and the magnitudes of the latter are what we call the components of $\boldsymbol{V}$ along the directions Ox, Oy. Whatever the co-ordinates, we can always find corresponding components for $\boldsymbol{V}$ and there is only one set of components per co-ordinate system.

More, we can find from the parallelogram law exactly how these components change as the co-ordinates are altered. If the co-ordinates undergo the transformation indicated in equation 1.8 the components V^a of $\boldsymbol{V}$ undergo the transformation

$$\bar{V}^a = C^a_b\, V^b \tag{1.16}$$

This is precisely the law we get from equation 1.14 for an entity T^a. So apparently the books were right after all. We are beginning to have a real respect for the definition of a tensor. We have already seen that it includes such very useful objects as scalars and vectors, and we begin to have confidence that with perseverance we shall find even more treasures hidden within it.

We shall not pause here to discuss such an entity as T_a which, having but one suffix, is also, presumably, a vector; but there are certain somewhat philosophical points about tensors in general which we can discuss with our present knowledge of vectors.

Why, for example, do we bother with components? That a vector has components is true. But components are such shifty, characterless things, always changing their attitude to comply with the dictates of co-ordinate transformations, while the vector itself is steadfast and unwavering, displaying a fine scorn for changes in mere co-ordinates. Would it not be simpler to deal directly with the vector instead of its ever-changing components? Unfortunately not! The powerful methods of mathematical analysis cannot be applied directly to the vector, but they are immediately applicable to its components. So whenever our problems become even slightly intricate we are forced to deal with vectors in terms of their components. This is why an understanding of how they change under co-ordinate transformations is so important. So frequent is the use of components in practice that, as we have seen in equation 1.14, we ultimately think of vectors as sets of components with definite transformation properties instead of as directed magnitudes adding in a certain way.

Yet there is something curious about this situation, for the components evidently must behave so as to reflect all the properties of their parent vector; and the parent vector's most characteristic property is its ability to exist without co-ordinates! The resolution of this paradox is important for the entire study of tensor analysis, and fortunately a compromise is possible. For we are not really interested in individual tensors; only in relations between them. For instance, though the scalar ds undoubtedly exists, it becomes of mathematical interest only when we can say what its value is and this ultimately implies a comparison with the standard yard, another scalar. Again, the momentum of a body becomes of interest when we can say something about it, and the law of conservation of momentum, for example, deals

with a comparison of momenta at different times. Any linear relation between vectors, such as

$$U - 5V = 8W \tag{1.17}$$

always can be written in the form

$$R \equiv (U - 5V - 8W) = 0 \tag{1.18}$$

so that our main interest turns out to be the vector zero!* It is evident from the parallelogram law that the components of the vector zero are themselves zero, this being true whatever the co-ordinate system. Thus for a zero vector the co-ordinate system has no influence at all on the values of its components and so if the equations

$$R^a = 0 \text{ (that is, } R^1 = 0,\ R^2 = 0) \tag{1.19}$$

are true in a single co-ordinate system they are true in every one. This is all we may reasonably expect from the components in their effort to emulate the aloofness of the parent vector. But we never need to use more than this for we can actually write equation 1.18 in terms of components as

$$R^a \equiv U^a - 5V^a - 8W^a = 0 \tag{1.20}$$

or as

$$U^a - 5V^a = 8W^a \tag{1.21}$$

which shows that any vector equation of the type of equation 1.17 immediately can be put into component form, and that if the component equations are true in one co-ordinate system they are true in all, and actually imply the validity of the original vector equation. For this reason we no longer bother to write down the original vector equation but regard the component equations as entirely equivalent to it. The law of transformation expressed in equation 1.16 for vectors is the counter part of the parallelogram law of addition and exhibits the essential properties needed for our argument. For, if the components V^a are zero, equation 1.16 shows that the components $\bar{V}^a$ in *any* other co-ordinate system will vanish also.

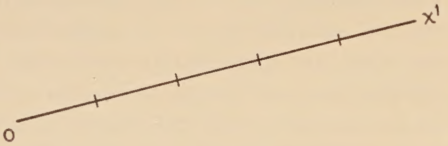


Figure 2. Segmented line representing voltage across the voltage coil of a wattmeter. The direction denotes the phase, and the scale the magnitude, of the voltage

The law of transformation 1.14 for tensors is of a very rare sort, giving to tensors all the properties we have just found for vectors. For example, any tensor equation can be put in the form

$$T^{ab\ldots}_{cd\ldots} = 0 \tag{1.22}$$

and this, if true in one co-ordinate system, is true in all, thus being as independent of co-ordinate systems as anything with components ever can be. Also, equation 1.14 ensures that a tensor has only one set of components per co-ordinate system. For if we start with some co-ordinate system, I; transform to another, II; from this to III; and so on in a circle till we come back to I, the tensor components also follow a circle, reaching their original values when we get back to I. Only the tensor law of transformation, and slight generalizations associated with relative tensors, have all these properties.

* Whittaker has described all of mathematics as variations on the theme 0 = 0.

The Tensor Discovered

Back to the hunt! The vector in equation 1.1 is hardly trying to conceal itself. It is (dx, dy), or in the new notation, dx^a. The proof? Well, it has two components per co-ordinate system and we have only to see how they transform. If the co-ordinates are transformed in accordance with equation 1.8 we have

$$\bar{x}^a = C^a_b\, x^b, \qquad (\bar{x}^a + d\bar{x}^a) = C^a_b\,(x^b + dx^b)$$

and, by subtraction, as is easily seen if the equations are written in full,

$$d\bar{x}^a = C^a_b dx^b \tag{1.23}$$

which is precisely the law of transformation expressed in equation 1.16. Therefore dx^a is a vector.

That was almost as easy as finding the scalar, but the rest is not so simple. Before we look for the second-rank tensor in equation 1.1 let us make yet another remark about vectors, also applicable in principle to any type of tensor.

We tested the claim of dx^a to be a vector by counting its components and seeing how they transformed. This point of view frees us from the impulse to look for something like

(1.24)

when seeking a vector, and opens up new possibilities, for a vector can actually be a collection of grotesque objects so long as their number and mode of transformation are correct, in which case a "space" will always exist in which the vector does look like the picture 1.24. The example of an alternating current will point several morals. For an alternating current superficially is not at all like this picture. An extremely important and by no means simple discovery was that it could in fact be represented as a vector, and even so the "space" in which it exists really has one axis time.

However, we can also represent this vector in other "spaces." For the sake of argument, let us imagine we do not know that an alternating current is a vector. We can devise an experimental method for discovering that it is a vector by using a special ammeter, such as is used in some a-c calculating boards. This instrument really is a dynamometer wattmeter with an arbitrary voltage on one coil and the alternating current in the other. We adjust the voltage on the voltage coil to some definite phase and some definite amount by twisting two knobs, and such an adjustment can be represented conveniently by means of a segmented line Ox^1 as shown in figure 2, the direction denoting the phase and the scale the magni-

tude of the voltage. With this setting Ox^1 let us assume that the meter reads V^1. Repeating the experiment for a new setting, Ox^2 we shall obtain a second meter reading V^2. We may look on such pairs of settings Ox^1, Ox^2 as co-ordinate axes in some "space" as indicated in figure 3, this sort of trickery being standard practice in mathematics. Suppose now that, instead of the pair of settings Ox^1, Ox^2, we take new ones $O\bar{x}^1$, $O\bar{x}^2$. The most general relation possible between Ox^1, Ox^2 and $O\bar{x}^1$, $O\bar{x}^2$ can be represented by precisely the formula 1.8 and we may therefore regard the use of different settings as a change of axes. Naturally, the new meter readings $\bar{V}^1$, $\bar{V}^2$ will differ from the old, and if the instrument is correctly adjusted, they will be related to the old readings by the formula 1.16. It follows from this that (V^1, V^2), or V^a, are the components of a vector!

Notice how this vector has shown itself. Not as a mathematical representation of $I \sin(\omega t+\theta)$ in a space having one axis time, but as a directly measured entity which can be represented in the manner of 1.24 if we invent a space whose co-ordinate axes are lines of the type Ox^1, Ox^2; whose co-ordinate axes are really nothing but the way we twisted the knobs of the instrument to adjust the phase and magnitude of the voltage! Had we looked directly for anything resembling 1.24 here we hardly could have been successful.

Be careful not to confuse this sort of vector with the sort found by Kron [*EE, Nov. 1936, p. 1220–42*]; those vectors and tensors belong to still other types of spaces.

So much for vectors for the present. Now for the second-rank tensor in equation 1.1: It is hiding with well-nigh perfect mimicry and we shall have to prod it

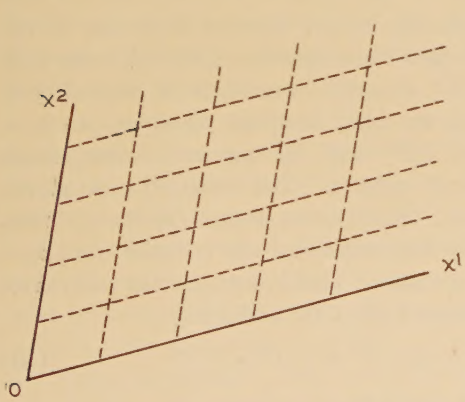


Figure 3. Co-ordinate axes formed by a series of hypothetical wattmeter readings arranged in a mathematical "space"

into showing itself by pulling on the co-ordinate system, keeping our eyes open for suspicious reactions.

We have already had occasion to remark that the right-hand side of equation 1.1,

$$(dx^1)^2 + (dx^2)^2 \tag{1.25}$$

must be a scalar. Let us test this.

We try a translation to a new origin:

$$\bar{x}^a = x^a + q^a \qquad (q^a \text{ constants}) \tag{1.26}$$

This gives

$$d\bar{x}^a = dx^a$$

and evidently

$$(dx^1)^2 + (dx^2)^2 = (d\bar{x}^1)^2 + (d\bar{x}^2)^2 \tag{1.27}$$

Nothing suspicious there. Try a rotation through an angle θ:

$$\bar{x}^1 = x^1 \cos\theta + x^2 \sin\theta, \qquad \bar{x}^2 = -x^1 \sin\theta + x^2 \cos\theta \tag{1.28}$$

If we work it out, we find, once more, that

$$(dx^1)^2 + (dx^2)^2 = (d\bar{x}^1)^2 + (d\bar{x}^2)^2$$

Even if we try a combination of translation and rotation we still get this result. Perhaps there is nothing to look for after all. Let us try one more transformation before we give up; this time a rotation through such an angle that PQ is parallel to the $\bar{x}^1$-axis. Then the $\bar{x}^2$ co-ordinates of P and Q are equal and so $d\bar{x}^2$ will vanish. Thus, instead of equation 1.27, we shall now have

$$(dx^1)^2 + (dx^2)^2 = (d\bar{x}^1)^2 \tag{1.29}$$

No longer a sum of squares of co-ordinate differences! A clew at last! If we follow the trail we are sure to find the tensor.

But I hear you object that it *is* a sum of squares and that, by accident, one of them happens to be zero; that it is only laziness which makes mathematicians leave out terms which happen to be zero.

Yes. I have to admit it. But the whole thing was only a trap and had nothing directly to do with the tensor we are after. I did it to force you into your present attitude of insisting that I recognize the existence of a quantity even though it happens to be zero. And now I am going to feel entirely at liberty to make you recognize the existence, not only of *two* quantities which have been pretending to be zero, but also of two other quantities which have been pretending to be unity—another symbol which mathematicians like to omit!

Make a transformation which stretches the x^1-axis but not the x^2-axis:

$$\bar{x}^1 = kx^1, \ \bar{x}^2 = x^2 \qquad (k \text{ a constant}) \tag{1.30}$$

Here we find

$$(dx^1)^2 + (dx^2)^2 = (1/k^2)(d\bar{x}^1)^2 + (d\bar{x}^2)^2 \tag{1.31}$$

and, genuinely, we no longer have the sum of squares of co-ordinate differences on the right. This can only mean that the notion that the square of the distance between two points is equal to the sum of the squares of their co-ordinate differences must be incorrect. Admittedly it is correct in Cartesian co-ordinates numbered in inches, but for more general co-ordinates it evidently is not so, and I now ask you to recognize that the $(dx^1)^2$ term on the left of equation 1.31 in reality is some number times $(dx^1)^2$ but that the number happens by chance to be unity. I shall label it g_{11} and write, instead of equation 1.1,

$$(ds)^2 = g_{11}(dx^1)^2 + (dx^2)^2 \tag{1.32}$$

Although in Cartesian co-ordinates g_{11} is unity so that we don't notice it, on the right of equation 1.31 it is clearly visible as $1/k^2$ and affords our first real glimpse of the second-rank tensor in equation 1.1.

By stretching the x^2-axis instead of the x^1-axis as before, we shall bring to light the existence of another quantity masquerading as unity, this time multiplying

$(dx^2)^2$. We label this new quantity g_{22} and revise equation 1.32 to read

$$(ds)^2 = g_{11}(dx^1)^2 + g_{22}(dx^2)^2 \tag{1.33}$$

What next? Let us see what happens when we change the angle between the axes. A simple transformation that does this, among other things, is:

$$\bar{x}^1 = x^1,\ \bar{x}^2 = x^1 + x^2 \tag{1.34}$$

This gives $dx^1 = d\bar{x}^1$, $dx^2 = d\bar{x}^2 - d\bar{x}^1$ so that

$$(dx^1)^2 + (dx^2)^2 = 2(d\bar{x}^1)^2 - 2\, d\bar{x}^1\, d\bar{x}^2 + (d\bar{x}^2)^2 \tag{1.35}$$

Not only does g_{11} show itself again, but also an entirely new type of term. I insist that it has always been there but has been hiding in the guise of zero. Shall we denote the coefficient of dx^1dx^2 by the symbol g_{12}, or perhaps $2g_{12}$? No. We must actually regard it as $(g_{12} + g_{21})$ with $g_{12} = g_{21}$, and then, our tensor being completely revealed, we may finally write equation 1.1 in the form

$$(ds)^2 = g_{11}(dx^1)^2 + (g_{12} + g_{21})dx^1\, dx^2 + g_{22}(dx^2)^2 \tag{1.36}$$

Notice how snugly it fits our notation. It is merely

$$(ds) = g_{ab}\, dx^a\, dx_b = g_{pq}\, dx^b\, dx^q = \dots \tag{1.37}$$

there being no reason for preferring one letter to another for a repeated suffix because of the implied summation. Because a repeated suffix may be replaced by a different repeated letter it is referred to as a "dummy" suffix, and the changing of repeated suffixes is an important part of the technique of tensor analysis.

We have yet to show that g_{ab} is a tensor. The number of components per co-ordinate system is correct so everything depends on how they transform. This is determined by the fact that though dx^a is a vector, the right hand side of equation 1.37 must be a scalar. We shall here merely *verify* that the law of transformation for the g's is

$$\bar{g}_{pq} = g_{ab}\, c^a_p\, c^b_q \tag{1.38}$$

The proof will not be difficult if the notation is expanded, but it can be taken on trust without what follows becoming incomprehensible. When the co-ordinates undergo the transformation shown in equation 1.8 we want $d\bar{s} = ds$. So, making play with various dummy suffixes, and using equations 1.23, 1.12, and 1.13, we have

$$\begin{aligned}(d\bar{s})^2 &= \bar{g}_{pq}\, d\bar{x}^p\, d\bar{x}^q = (g_{ab}\, c^a_p\, c^b_q)\ (C^p_c\, dx^c)\ (C_d\, dx^d)\\ &= g_{ab}(c^a_p\, C^p_c)\ (c^b_q\, C^q_d)dx^c\, dx^d = g_{ab}\, \delta^a_c\, \delta^b_d\, dx^c\, dx^d\\ &= g_{ab}dx^a dx^b = (ds)^2\end{aligned}$$

A comparison of equation 1.38 with equation 1.14 shows that g_{ab} is a genuine tensor. That it is of the second rank merely means that it has two suffixes.

What use is it now we have found it? Haven't we managed very nicely without it all these years? Apparently so—but in actuality not at all so! We cannot even begin to talk about the concept of distance without implicitly referring to the existence of g. It is as much a part of nature as π or the Maxwell equations, and is always present in equation 1.1, however well hidden. It acts as a counterpoise to the violent fluctuations in the values of the co-ordinate differences dx caused by changes in the co-ordinate system, and throws its weight in the exact direction and to the precise extent needed to keep the value of the quantity $g_{ab}\, dx^a\, dx^b$ absolutely undisturbed. Without some such unchanging quantity as $g_{ab}dx^a dx^b$ the idea of distance could find no mathematical expression, and because of its fundamental role in this connection, g_{ab} is called the *metrical tensor*. Although it is not possible to give a simple picture for g_{ab}, the best in two dimensions being two imaginary lines, we see that it is an objective reality of the first importance. Yet it was not really isolated till the nineteenth century!

The final thing to look for in equation 1.1 is the vector of the type T_a, and before we go after it we must straighten out the whole matter of the two places for putting in the suffixes on a tensor. The law of transformation expressed by equation 1.14 shows that whether a suffix is upstairs or downstairs has a great effect on the transformation law obeyed by the tensor. The two types of suffixes induce complementary types of transformations which, under certain simple conditions, completely nullify each other. Let us look at a simple example of this, which, incidentally, will materially assist our hunt. We consider two vectors of different types T_a, V^a. They transform, under the co-ordinate transformation 1.8, according to the laws

$$\bar{T}_a = c^c_a\, T_c,\quad \bar{V}^b = C^b_d\, V^d \tag{1.39}$$

where we have used such letters for suffixes that we shall not have to make unnecessary changes of dummy suffixes in the later argument. From equation 1.39 we see that the four quantities $T_a V^b$ transform, under 1.8, according to the law

$$\bar{T}_a\, \bar{V}^b = c^c_a\, C^b_d\, T_c\, V^d \tag{1.40}$$

This being precisely the tensor law for a tensor of the type T^b_a, as is easily seen from equation 1.14, it follows that the quantities $T_a V^b$ actually constitute a second-rank tensor. Now let us see what happens when we put $b = a$ so that we have $T_a V^a$ and, by our convention, must sum over the dummy suffix a. The notation is so clever it is well ahead of us! For if a is a dummy suffix and thus summed, it is really lost to us and the notation indicates that we now have a scalar. This is actually the case, since we have, by equations 1.40, 1.13, and 1.12,

$$\bar{T}_a\, \bar{V}^a = (c^c_a\, C^a_d)T_c V^d = \delta^c_d\, T_c\, V^d = T_c\, V^c = T_a\, V^a \tag{1.41}$$

which is the correct law of transformation for a scalar.

Such an equation between tensors as, for example,

$$T^a_{bc} \equiv (2U^a_{bc} - \frac{7\pi}{16}\, V^a\, W_{bc} + \sqrt{-1}\ \ X^{ae}_c\, Y^f_{bef}/Z) = 0 \tag{1.42}$$

illustrates all the important rules for manipulating tensors and these are so obvious that to explain them would but confuse matters. Note that we may not divide by tensors, except by the simplest type, scalars; and that if we do not count the dummies, all the terms have the same suffixes.

We now know enough to entrap the second vector in equation 1.1. It is merely the quantity

$$(g_{ab}\, dx^b) \tag{1.43}$$

and we shall leave it to the reader to convince himself of this and to note how the scalar character of the right-hand side of equation 1.37 fits in with the illustration $T_a V^a$ and with the general rules contained in equation 1.42.

And now our hunt is ended.

Should the reader feel disappointment at the size of the bag let him remember that it is neither his fault nor, I hope, mine, but solely that of the tensor calculus itself. We have found traces of almost every important idea in the tensor calculus that does not involve differentiation and there is nothing more to learn in the way of essential general ideas.

It is extraordinary that so apparently empty a subject—a notation plus a law of transformation—should have such vast importance, but we shall find ample evidence of its powers in part III.

In case you are interested, an upper suffix is called contravariant; a lower suffix, covariant. But don't try remembering which is which just yet. It will be obvious after we come to covariant derivatives in part II.

Culture in This Age of Science

In an address reported in a recent issue of *Vital Speeches of the Day*, W. F. G. Swann, director of the Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa., discussed the problem of the use of leisure that has been made available by the accomplishments of science. Although warning that it is difficult to appraise the present in relation to the past and future, Doctor Swann pointed out that one who views the world today cannot escape the impression that the change man has seen in the last hundred years does not find its counterpart in any like period of the world's history.

At the beginning of the past century, humanity was divided roughly into two classes of beings: the man who toiled and whose whole life was spent in the effort to survive, and the man of wealth. The latter had leisure for cultural pursuit; but, even to him, the realms of culture were limited to a few fields, and these he pursued in his own immediate surroundings with but little personal contact with his fellow men, other than the few whom he had gathered as guests around him. It was an age of culture, but culture for the few.

Then new forces came to life. Railroads, electrical machines, and automobiles were created, and that great structure which is modern civilization was being built as fast as it could be planned and constructed in the age of science. The arts associated with culture became left in larger and larger measures to professionals. The skill of the professional increased while the skill of him who lived in the class of cultured listeners of yore decreased as he became more and more an onlooker and less and less a participant.

As an era is approached in which all men, even the workers of humble degree, have time for things other than the battle against starvation, the use of leisure becomes a problem of fundamental importance. Few people are more unhappy than those who have attained middle age and who have never devoted themselves seriously to any constructive pursuit. To be satisfactory, a cultural activity should, like a good game, have in it those elements which render possible continued improvement without the possibility, or at any rate, the easy possibility, of an approach to perfection. In an age in which a large proportion of mankind may look forward to a reasonable amount of leisure in the future, it may become as necessary to provide a basis for the utilization of that leisure as it is to provide for a man's health.

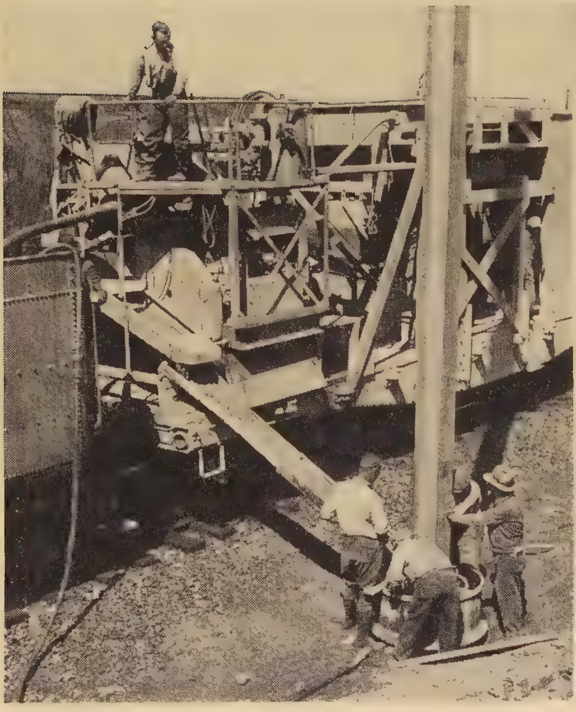
"When one stresses the needs of cultural pursuits," said Doctor Swann, "one is often met by the frown of the utilitarianist, who demands that that which man does shall be of use. But what, in the last analysis, is the purpose of all the things which are 'of use'? The whole world is a gigantic machine with parts of ever-increasing complexity striving toward some goal which as yet seems ill defined. What is that goal? Is it merely security from sorrow, and freedom from hunger and pain? If such is the only goal, universal suicide may well present itself as a worthy candidate to secure that end. If it be not the only goal, there remains the positive realization of happiness, and this state, in which man is happier alive than had he not been born, is the one which I present to you as the ideal. . . ."

Science may bring to realization an economic state where man need vie no longer with man for possession, and nation need strive no longer with nation for conquest. In this millenium there may be strife, but strife of intellect, which exists among men of science even today. If only the fruits of science could be properly administered throughout the world, this kind of combat would represent all the wars that need remain. Destructiveness would be replaced by a constructive strife.

In conclusion, Doctor Swann said "Great is the heritage which has come to mankind within the generation that now lives; but, the elements of that heritage are disordered in their relationships one to another. The blessings of science can be made to serve many unworthy ends. Even now, in ever-increasing crescendo, we hear the voices of propaganda calling through the appeals of flattery, of humanity, of pride, and all the other portals of weakness in the heart of man, to beguile the spirit of the nation to a strife for principles whose inner content is hard to fathom from the clothes they wear. Great is the responsibility and great the opportunity for one who . . . assumes at this time the task of molding the vision of the nation's youth, that it may know how to judge between propaganda and the voice of truth, that it may recognize greed masquerading in the cloak of righteousness, that it may know reality from shadow, and that it may learn to put what nature has yielded to the service of humanity, and to replace the poisonous satisfactions and greedy hopes which infest the nations of today with the joy which comes from kindliness toward all men."

Extension of The Pennsylvania Railroad's

By H. C. GRIFFITH
MEMBER AIEE



THE EXISTING single-phase electrified system of The Pennsylvania Railroad, completed in the early part of 1935, extends from New York, N. Y., through Philadelphia, Pa., to Wilmington, Del., Baltimore, Md., Washington, D. C., and Potomac Yard, Va., for passenger and freight service north and south; and from New York to Philadelphia and Paoli, Pa., for service east and west. Including the trackage used for suburban service, this electrified system now covers a route of 373 miles with 1,343 miles of electrified track.

The results of this present electrified system have been so satisfactory to the railroad and to the public that the company decided to proceed with an extension which will complete in effect the program announced in the fall of 1928. The lines now being electrified are: (1) The main line from Paoli, 20 miles west of Philadelphia, through Lancaster to Harrisburg for passenger service to and from the west; and (2) the low-grade freight line from Morrisville, Pa., near Trenton, N. J., via Columbia to Enola Yards near Harrisburg; the freight line from Columbia, Pa., following the Susquehanna River to Perryville, Md.; and the freight line from Monmouth Junction to South Amboy, N. J., with connecting branches and yards. This new work involves the electrification of 315 miles of line and 773 miles of track.

In general the same type of system of delivering power to the moving trains will be employed in the extension as is now in use. An 11,000-volt single-phase 25-cycle trolley wire, supported by a catenary type of messenger construction, is used over the center of each track. Transmission from power-supply points to substations is over 132,000-volt single-phase 25-cycle two-wire transmission circuits supported on the same structures that carry the catenary system. Substations, which are of the outdoor type, average from eight to ten miles apart, although in some cases this spacing is as much as 13 miles.

General Features of Construction

Catenary structures are spaced approximately 20 per mile, and the poles are of an H-section, simple and easily adapted to the required designs. The principal structure design is called the "cross catenary," and consists of guyed poles on each side of the right-of-way with a cross-wire span over the tracks to support the weight of the catenary structure. The guy anchors usually are cast-iron cones, but where greater strength is required, a reinforced concrete anchor is poured in place. The pole foundations

Based on a paper presented at the AIEE Middle Eastern District meeting, Akron, Ohio, October 15, 1937.

H. C. Griffith received the degree of electrical engineer at Lehigh University in 1914, following which he entered a special engineering apprenticeship course with the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa. In 1915 he became a draftsman for The Pennsylvania Railroad, and has remained in the employ of that organization continuously. He became electrical engineer in 1935.

Electrified System

The single-phase electrified system of The Pennsylvania Railroad now in operation includes 1,343 miles of electrified track. An extension, now nearing completion, will increase the number of miles of electrified track to 2,116. Design and operating details of the 11,000-volt 25-cycle system, together with some interesting side lights on protective devices and the communication network, are presented here.

The photographs on this and the facing page show, left to right: pouring concrete base for pole; using outriggers over track kept in use for steam operation; workmen in boatswain chairs, adjusting catenary hangers and attaching wire clips; one of the class-CG1 locomotives in use on the electrified sections

have been simplified, and generally consist of a metal tube sunk in the ground and back-filled with concrete after the pole has been inserted and aligned. The top surface of the foundation is dressed off by metallic split forms.

Where the use of guys is not practical, a self-supporting structure known as the "crossbeam" type is used. The cross-wire span in this type of structure is replaced by a steel crossbeam stiffened by sag braces, by which means the poles are made self-supporting. Where placing poles on each side of the right-of-way is undesirable or unnecessary, such as on one- or two-track construction, and provided one pole only is required for the support of the transmission circuits, a structure known as the "bracket" type is used. This is a single guyed pole supporting a bracket from which the catenary construction is suspended.

An unusual feature of these general types of structure is their large degree of longitudinal and torsional flexibility together with transverse strength.

The catenary system consists of a number 4/0 bronze trolley wire, having approximately 55 per cent equivalent copper conductivity, supported by a five-eighths-inch composite messenger cable having 7 copper-covered steel core wires and 12 surrounding copper wires. This composite supporting messenger provides additional conductivity somewhat greater than the conductivity of the five-eighths-inch low-conductivity bronze wire generally used up to this time, and at the same time furnishes adequate strength for supporting the catenary system. On all tracks used for high-speed passenger service, where greater flexibility in the catenary system is desired, and at points where greater conductivity is required, an auxiliary messenger of number 4/0 solid copper is carried just above the contact wire. This messenger supports the contact wire by means of clips staggered with respect to the hangers, which in turn support the auxiliary messenger from the main messenger. The insulation of the catenary system is ample for maximum reliability, and consists of three ten-inch standard cap-and-pin suspension insulators each five and three-quarter inches in length.

The catenary contact system over each main track is electrically independent of that over other tracks, except as connected through circuit breakers at the substation bus. The trolley wires are sectionalized back of crossovers and at such other points as required to isolate a failure and restrict it to a relatively small section.

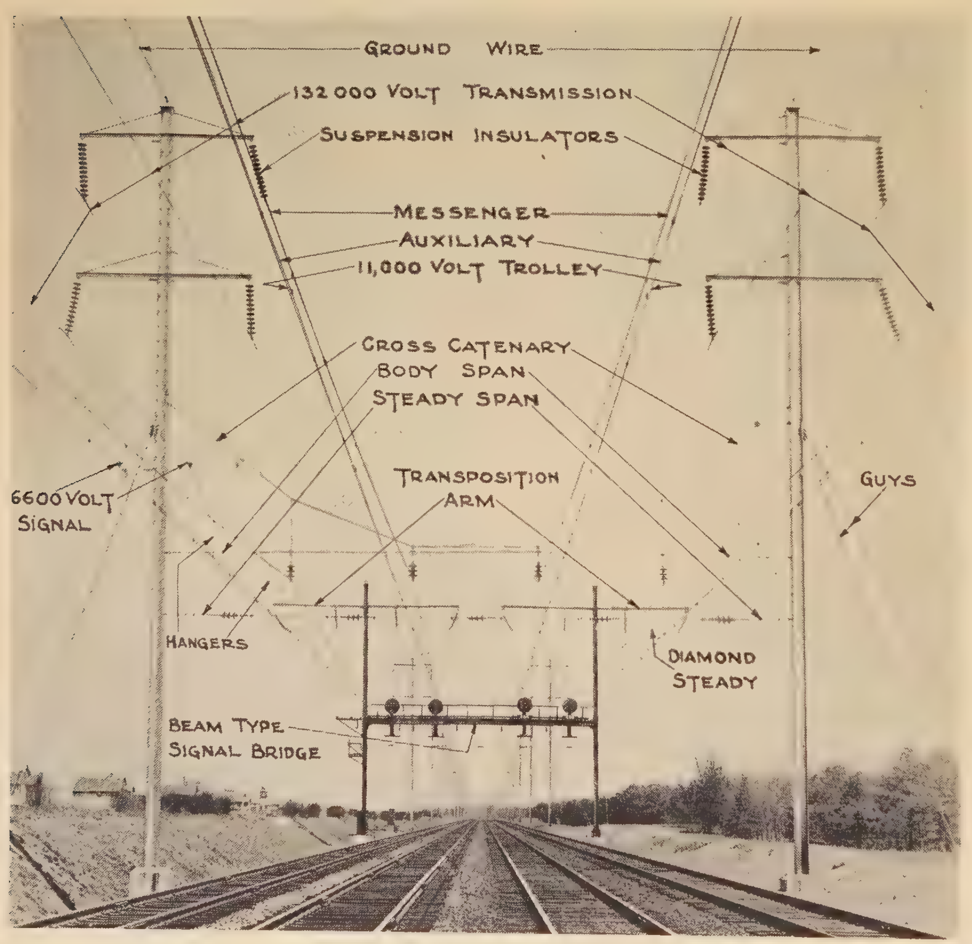
Transmission System

The 132,000-volt transmission-line conductors are carried on the structures above the catenary system, supported eight feet from the poles on crossarms. The insulator strings contain nine standard ten-inch suspension units. Each of the two wires of a circuit is normally at a balanced potential of 66,000 volts to ground, inasmuch as the midpoints of the 132,000-volt step-up transformer windings are grounded through 330-ohm resistors at the supply points. The conductors are either 250,000-circular-mil hollow copper cable or 477,000-circular-mil aluminum cable, steel reinforced. Each substation usually is supplied by two or more transmission circuits. A number 4/0 stranded-copper ground wire is carried on the tops of the poles about 12 feet above the upper transmission wires. A 6,600-volt single-phase 100-cycle-signal power-transmission circuit composed of number 1/0 conductors is carried on the same structures.

This extension of the electrified system involves building 21 additional step-down transformer substations, additions to the transformer capacity in two of the supply stations and changes and additions in many of the existing substations. Generally the design of substations is the same as previously used, except for such modifications as have been made in the interests of economy. The outdoor type of structure used has been simplified as far as practicable.

A step-down transformer with a continuous rating of 4,500 kva has been adopted as standard size, the design of the transformer receiving particular attention to secure ample overload capacity to fit the characteristics of the railroad power load, and to have high impulse-voltage rating with carefully co-ordinated insulation. Co-ordinating gaps are attached to the bushings and to the transmission lines in and near the substations. Lightning arresters usually are not used on the 132,000-volt circuits. Transformers are connected to the transmission circuits by means of horn-gap switches without circuit breakers. The 11,000-volt side of the transformers is connected to the substation trolley bus through circuit breakers and the bus is divided into two sections by a bus tie circuit breaker to sectionalize the trolleys in each direction from the substation.

Trolleys are fed separately through high-speed circuit breakers, which are rated at 1,500 amperes continuously and interrupt short-circuit currents in less than one cycle on a 25-cycle basis, or in approximately 0.04 second. Owing to the increase in system capacity as the electrification has grown, over 100 of these circuit breakers are being obtained with an interrupting rating of 65,000 amperes as compared with the previous rating of 50,000 amperes. Upon completion of the new electrification, more than 500 high-speed circuit breakers will be in service. One particular feature of the later designs of these circuit breakers is that they contain little or no oil, which simplifies the maintenance work and greatly reduces the fire hazard in case of damage.



Typical main-line four-track construction with "cross catenary" type of supporting structures and with four transmission circuits. In the background is a signal bridge, simplified and combined with an electrification structure. A transposition in the transmission lines is made at this signal bridge

Special Features

Substations are unattended, and on the present electrification between New York and Wilmington most of them are electrically controlled directly from nearby signal-interlocking towers Equipping some substations with direct control has been found to be uneconomical and supervisory control has

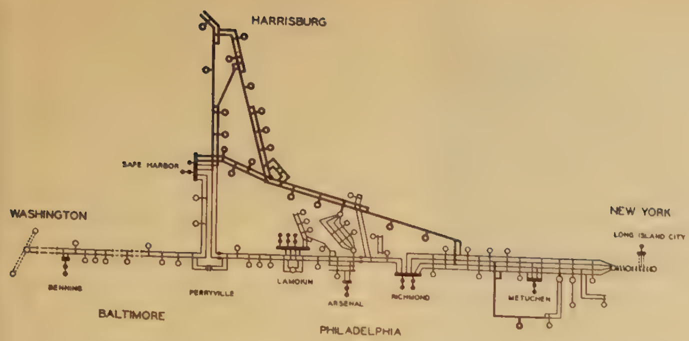


Diagram of the transmission circuit for the electrified system and the extension now nearing completion and (right) a map of the area covered by the electrified lines

been used for the operation of a substation. When the electrified system was extended south of Wilmington to Washington, the most suitable location for several substations was too far from an interlocking tower to make direct control economical and supervisory control with remote metering was used instead for six of the substations. This placed the stations directly under control of the men in charge and has been found to be efficient and reliable and somewhat faster than the previous system of handling the operations by telephone instructions to the interlocking tower operators. The supervisory control system not only provides remote control, but also calls immediate attention by visual and audible means to any automatic operation and provides at all times positive indication of the position of circuit breakers and switches in the substations.

At the present time 14 of the 40 existing transformer substations are operated by supervisory control. Because previous experience indicated the reliability of such a system, a uniform centralized control system for all of the substations on the new electrification was designed. This system is simplified by the location of 18 of the 21 new substations on one railroad division; consequently, all but three substations come under the supervision of one headquarters office, and two of the remaining three could be incorporated as part of an existing system at another point. The remaining substation is located on a freight branch line and will be controlled by supervisory control from an interlocking tower from which is controlled the adjacent existing substation.

The point from which the group of 18 new substations will be controlled is in Harrisburg. These substations are divided into two zones, each zone comprising about half of the main passenger line and half of the low grade freight line. The two-wire "code" type of supervisory control is used, each of the substations being normally operated over a separate pair of telephone wires. The substations are further divided into groups, separating the passenger and freight territory in each zone. Each of these four groups, known as metering groups is provided with a pair of spare wires for emergency operation of any substation in the group. If the wires over which a substation is normally operated should fail, operation can be transferred to the spare wires by remote control from the dispatching office.

At the dispatching office a set of meters is provided for each of the metering groups, and indications are brought over a pair of metering wires for each group. Any one meter reading in each group thus may be obtained at the same time from a substation in the group without interfering with the normal operation of the supervisory control system.

Power Supplies and Parallel Operation

Power at 25 cycles, single phase is supplied to the system at seven separate supply points, and except for the supply from 25-cycle turbogenerators at the railroad's own power plant at Long Island City, N. Y., the energy is purchased from power companies. This energy is obtained from interconnected power company 60-cycle systems, with the exception of one 25-cycle water-wheel generator that feeds the railroad circuits direct, and is converted to 25 cycles by means of frequency-changer motor generator sets. Purchased power is obtained under two separate contracts: one in the area from New York to the Susquehanna River on the south and to the west at a point between Lancaster and Paoli on the new electrification; the other covers the area from the Susquehanna River south to Washington and from the westerly sectionalizing point to Harrisburg and the Enola Yards. This arrangement adequately protects the service by providing power supplies at points well distributed along the route, at the same time permitting the supply of enough power from each source to ensure enconomy of production.

Normally the supply stations are operated in parallel through the railroad's 25-cycle transmission lines. As mentioned before, no circuit breakers are connected in the 132,000-volt lines at the substations to switch the transformers or the lines between substations under load or automatically during faults. Circuit breakers are provided, however, at several points in the 132,000-volt lines to isolate the areas served by the principal supply stations and to separate the two supply systems.

When sectionalizing circuit breakers are opened, corresponding "phase breaks" are opened in the trolleys at the same substation, thus preventing a passing train from momentarily tying together the trolleys fed from separate sources, which may be out of phase. These circuit break-

Load dispatcher's office, with manually controlled model board indicating all transmission lines, power supply points, and transformer substations. Load-totalizing telemeters are shown in the background

ers are opened automatically when the 60-cycle systems back of the 25-cycle generators are out of step. If there is a possibility that this may occur because of lightning storms or during similar emergencies, the circuit breakers may be tripped remotely by an operator at the principal supply stations or in the power supervising office of the railroad company.

Prior to the extension of the electrification to Harrisburg, automatic operation of the 132,000-volt circuit breakers was not provided for short-circuit or ground faults on the railroad's transmission lines, but because extending the system necessitated an increase in the length of the circuits, automatic operation now is provided. This reduces the length of circuit tripped out by the faults, and during a short circuit the principal supply points are segregated to prevent such a fault from causing instability of the system. A line that becomes faulted to ground is relayed in such a way as to trip the sectionalizing breaker in that line only and then to isolate completely the section of line at fault. If a line becomes short-circuited, the relays trip sectionalizing breakers on both the paralleling line and the line at fault, except at Zoo substation, in Philadelphia, where tripping the sectionalizing breakers is not deemed necessary. After the sectionalizing breakers have opened, the section of the line at fault is completely isolated.

Operation of Power Supply and Distribution System

The operating personnel of the substation, trolley switching, and power supply systems has been organized in a manner similar to the train-dispatching organization. Each subdivision or zone of the electrified system has a power director who is responsible for all switching in his territory. Switches are controlled directly by the power directors in territory where supervisory control is provided, as on the new part of the system; otherwise the power director telephones instructions to the signalman in an adjacent signal tower, and the signalman operates the switches. Power directors are furnished with complete telephone service to all switching points over which they have supervision, to the train dispatchers and to all telephones along the right-of-way for the purpose of receiving reports and issuing clearances for maintenance operations. Each power director is furnished with a "model board" on which the circuits in his area are shown in miniature with red and green lights to indicate the positions of all switches, enabling him to know at all times the condition of the circuits and thus to act promptly and intelligently. In the past the model board has been operated manually from a keyboard; however, at Harrisburg the model board for the new electrified territory will indicate most of the operations directly as they are performed by interconnection with the supervisory control system.

In addition, the provision of separate centralized supervision over the transmission circuits and power supplies has been found essential, so that switching and manipulation of circuits locally will not interfere with interdivisional circuits and so that the supply of power will be controlled economically and effectively throughout the entire system. The system load dispatcher, who is located at Philadelphia, is responsible for this supervision. His office is equipped with a model board on which all power supply stations, transmission circuits, and substation connections are indicated. Trolley switching and local circuits are omitted. He is connected by a telephone system to all power directors and power-supply stations; moreover, he is provided with an elaborate telemetering system indicating directly the load on each supply station and the division of load between the sections of the electrification.

Railroad Communication System

One of the important problems involved in electrifying a railroad, although not usually associated with the subject, is the modernization and improvement of the railroad's telegraph and telephone system. Under steam operation the communication circuits usually are open wires on poles located close to the railroad, but physical and electrical co-ordination of these circuits with the electrification requires relocation of the communication cir-

cuits. Between New York and Washington, prior to the electric operation, the railroad's communication lines were placed in cable in underground duct lines; the results were excellent. However, in order to provide equal results at a lesser cost, the communication circuits on the electrification to Harrisburg will be carried in armored cable on treated wood poles along the edge of the right-of-way. The circuits are carefully loaded and balanced and provide a communication system much superior to that formerly in use. The new cables provide for the communication system of the electrification together with its remote metering and supervisory control circuits, as well as the communication system for the general railroad purposes.

Railroad Signal System

Another important factor in electrification is the arrangement of the railroad signaling system to meet the conditions of electric traction. First, the wayside signal structures themselves must be so located as to be compatible with the location of the catenary supporting structures, and must be so spaced as to provide for the higher train speeds resulting from electrification. Second, since the track rails carry not only the signal circuits but also provide a return circuit for the traction current, the signal system must be designed to avoid interference between the two functions. Finally, the signal system provides for "cab signals," giving in the locomotive cab a continuous indication of the position of the wayside signal last passed, and thus indicating any change in conditions ahead.

The signal system adopted to fulfill these purposes is known as the "universal code" system. "Position light" wayside signals are used, and miniature signals of similar appearance give the same indication in the cab of the locomotive. The d-c or 60-cycle signal systems in use prior to electrification are removed and a 100-cycle universal-code system replaces them. This system provides indications by means of continuously recurring impulses of 100-cycle current in the rails. These impulses, which are transmitted by physical connections to the wayside signal and picked up by the detector bar on the locomotive, by proper tuning and amplifying equipment are translated into the actual signal indication. This signal system is not affected by stray currents of other frequencies, and even should current of the same frequency be imposed on the rails, no false clear signal can result unless the current flows at the proper intermittent coded impulses. This signal system is safe, requires a minimum number of wayside wires, and the over-all cost is relatively low.

At the present time the new work is progressing at full speed. Nearly 10,000 men are employed directly on the project and perhaps as many more are employed in the industries furnishing materials and equipment. This extension, giving complete electrification of the lines from the eastern seaboard to Harrisburg, will effect substantial operating improvements and economies and will enable the Pennsylvania Railroad to realize an increased return on its entire investment in electric service. It will further provide greater reliability, higher speed, and smoother handling of trains, with a consequent benefit to the public. In addition, the new electrification will increase materially the capacity of the railroad, as it did in the present electrified territory, without the construction of more tracks. It will accomplish for the east-and-west movement operating improvements comparable with those gained by the electrification of the New York–Washington service.

After electrification, many heavy steam locomotives now in use east of Harrisburg will be transferred to other parts of the system, thus increasing the efficiency of handling freight and passenger traffic in territory where steam trains are operated. Upon completion of the new work the Pennsylvania Railroad system will have a total of 2,677 miles of electrified track, or 41 per cent of the total electrically operated standard railroad trackage in the entire United States.

One of the new substations, which contains two 4,500-kva transformers and four high-speed trolley circuit breakers, and is fed by two 132-kv transmission circuits entering the substation from opposite directions

The maintenance of reliability and continuity of electric power service is assumed to be an almost inherent function of the local electric utility company; but how much this reliability depends upon the physical interconnection of power systems is not generally realized. An engineer widely recognized as an authority describes here typical operating and economic advantages based upon experiences with an interconnected and co-ordinated system that extends over most of the area east of the Mississippi River.

Huntington, W. Va., was flooded by the waters of the Ohio River during January 1937, as shown here; but the combined facilities of interconnected electric power systems worked together to spare the community from the danger and suffering that follow failure of power service in such areas

Interconnected

THE SUBJECT of interconnection for a long time was linked with its apparently inseparable twin "superpower." Both of these subjects, and particularly the latter, aroused much public interest a decade or so ago, and a great deal of discussion, centered about them. But lately both have received little public comment. That the interest in superpower has lagged is not particularly regrettable, since the word had more spectacular appeal than economic validity. The diminution of discussion on interconnection is less understandable and really is deprecable.

This abatement of interest is lamentable, first, because it is a subject of vast importance technically, economically, and socially; and second because an impartial appraisal of the accomplishments of the electric-power industry in the United States—that is, the private electric utilities in the United States—during the past 50 years, impresses one with the magnitude of the task of interconnecting and co-ordinating electric utilities, and with the magnificence of the manner in which it has been accomplished. This has given to the United States an electric-supply system unparalleled anywhere on the face of the civilized globe, and is in no small measure responsible for the industrial progress in this country.

Yet, the average electric utility customer, or even the engineer not devoting his entire time primarily to a study of the power-supply problem, has little conception of either the work or the products of the work of carrying out interconnection and integration, because his knowledge of electrical systems does not disclose the magnitude and the difficulties of the task.

What Interconnection Is

Basically, interconnection of utility systems involves the idea of so operating the component parts of a system or a group of separate systems that under all conditions generation and transmission are accomplished in the most efficient manner. This means that the power supply will be operated without any substantial sacrifice of reliability of supply; indeed, with actual enhancement of that reliability under normal conditions, and with positive assurance of continuous service during unforeseen emergencies against which no provision is economically feasible, except by making available sources of power supply from points remote from the immediate area subject to the emergency.

The philosophy behind interconnection, then, postulates the idea of unstinted mutual help in times of need,

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up to the limit where the helper himself is jeopardized. This is important because in other businesses a mutual joining of forces to that extent seldom is permitted to exist. Yet in power systems the idea of operating systems truly interconnected has been closely embraced. It is a sound idea, and sound business, provided that the technique of operating interconnected can be so evolved as to reduce the self-jeopardy of the aiding part of the system, or of the aiding system, to a negligible amount. Those who have analyzed this problem extensively and understand its implications are following it, fully satisfied that it is merely a question of technique, and that the technique of operating successfully on the interconnected basis has been well developed and is being perfected more every day.

From this definition many so-called interconnections apparently are not interconnections in the true sense of the term, because the amount of help they make possible and the resources they offer for emergency use are definitely circumscribed and limited. Figure 1 is an example of a poor interconnection, for between system *A* and system *B* there are two transformations and the maximum power that can be transferred over line *L* is limited not only by the impedance drops through the two transformer banks, but also by the thermal limitations of these transformers. Only rarely is the thermal limitation of the transformers even approximately equal to the thermal limitation of the line itself. Or consider figure 2, in which system *A* interconnects with system *B* and with system *C* through lines *LB* and *LC*, respectively. Here again not only is the extent of help that *A* can render to either *B* or *C* limited, but also in emergency *B* and *C* are limited in the help that they can render each other because of the double impedance drop of transformer banks *TB* and *TC* and their thermal limitation.

Several such interconnections have been built in spite of the fact that the conditions would have permitted the omission of transformers, because those responsible for the interconnection were not certain of the soundness of the idea of operating interconnected systems. But such poor interconnections fortunately have been few, and several interconnections started with that idea subsequently have been altered to operate more closely interconnected.

ectric Power Systems

By PHILIP SPORN
FELLOW AIEE

Achievements in Interconnection

To demonstrate some of the things accomplished by means of interconnection in the United States, the American Gas and Electric Company's system has been chosen, purely for convenience, as a typical interconnected system. Figure 3 shows the system extending into the seven states of Michigan, Indiana, Ohio, West Virginia, Virginia, Kentucky, and Tennessee. It does not show The Scranton Electric Company system extending through the Lackawanna Valley or the Atlantic City Electric Company system covering the southernmost fourth of the State of New Jersey, both of which are parts of the composite system.

The parent company was organized in 1906 and originally owned properties at Marion and Muncie, Ind.; Canton and Bridgeport, Ohio; Wheeling, W. Va.; and others in the surrounding territory. By 1913 these companies had grown and others had been purchased where they could fit in with the idea of integration, which even in those days was a dominating policy in the evolution of the company. This was effected in typical fashion in the Wheeling, Steubenville, and Canton districts. Eventually a need for larger capacity in these districts became evident, and because of the lack of an adequate local supply of cooling water, especially in the Canton area, it became apparent that the most satisfactory way of increasing the generating capacity was to interconnect the properties and serve them from larger and more efficient power stations situated favorably with respect to fuel and water supply. The result was the construction of the history-making Windsor power station, located at the mouth of a coal mine on the Ohio River 14 miles north of Wheeling, W. Va. With it was erected the first 132,000-volt transmission line in the middle western region of the United States and as a consequence the power system throughout an area of several thousand square miles became integrated. Windsor was a historic landmark in another sense: It was the first jointly owned and operated large power station and thus served as an interconnecting and integrating medium between two otherwise separate power groups, the co-operating organization at Windsor being the West Penn Power Company.

This integration of resources was continued over the entire area as new properties that could be so integrated were acquired. During the period from 1924 to 1929 expansion was particularly rapid; properties were "tied together" by high-tension transmission lines, and inefficient generating units were abandoned. By the end of 1929 most of the properties were virtually tied together by a 132,000-volt bus.

By 1925, 132,000-volt lines had been extended from South Bend, Ind., to Lima and Fostoria, Ohio. Previously built 66,000-volt lines connected this region with Philo plant over a long north-and-south transmission network running from Crooksville to Fostoria, Ohio. The lack of proper sites for generating plants in the Canton, Fostoria, and Lima areas, mainly because of the inadequacy of the supply of cooling water, necessitated extending into this area the high-tension transmission system whenever the 66,000-volt system became inadequate. By 1929 the loads in the North and Central Ohio area had grown so much that additional generating capacity was required; consequently, the Philo-Shelby-Fostoria 132,-

000-volt line, which connected the Ohio and Indiana territories, was constructed. Besides satisfying the immediate load requirements this tie effected material savings from replacing energy formerly generated in Indiana by energy produced at Philo and other plants having fuel costs substantially lower than in the Indiana plants. Thus, during the depression and continuing now during all light-load periods, a large part of the generation in Indiana has been replaced by generation at Philo and at other plants in the eastern section. The resulting saving for the past five years on fuel costs alone amounted to, roughly, $1,-500,000. To do this, however, required a double circuit

Figure 1. Diagram of a poor type of interconnection between two power systems, in which the maximum power transfer between the systems is limited by the voltage drops in the impedances of the transformer banks and by thermal limitations of the transformers

between Philo and Fort Wayne. This interconnection has produced a further saving by diversity interchange between the American Gas and Electric Company system and the Northern Indiana area, which in turn is interconnected with the Chicago area.

Here, then, is an interconnection, typical of many others, which has paid its way on a basis of economy interchange, has contributed to conservation of natural resources through the utilization of more efficient fuel-burning equipment, and has contributed materially to lower cost of electric service. This interconnected system has a peak load of about 825,000 kw, with an annual energy output of just under 4,500,000,000 kilowatt-hours. This system has also about 20 interconnections with outside companies, some of which are used for emergency operation only; others are for day-to-day interchange. The combined capacity of these interconnections is 550,000 kw.

Similar interconnection and co-ordination has been embodied in the power system serving New York City; on the Niagara-Hudson system, one of the outstanding power systems of the entire world; in California, where interconnected systems having a generating capacity of over 3,700,000 kw operate in parallel; in the Chicago district; in the southern district of the Commonwealth and Southern Corporation, which has a system annual peak of over 900,000 kw with an output of 4,500,000,000 kilowatt-hours; in the system around Philadelphia; in the system of the Pennsylvania Power & Light Company; and in the system of The Scranton Electric Company.

Thus far the discussion has been about the evolution of co-ordination and interconnection on systems representing either one individual company or systems under unified control. But that interconnection has been achieved throughout the country on a vast scale can be seen from an examination of figure 4, which shows the major electric systems and transmission networks in the United States. Except for some gaps which are discussed more fully later, the region east of the Mississippi River is almost completely netted with high-tension lines. Immediately west, is a less dense netting and integration in the Great Central Plains, but the reason for the lessened co-ordination obviously is due to the predominantly agricultural character of much of the territory. The Great Western Plains coming up to the eastern slope of the Rockies have comparatively few high-tension networks. Here the population density and the concentration of industry are too low to warrant or require a high scale of electrical development. A totally different situation exists in the Northwest and on the West Coast. The integration in California already has been mentioned, but nothing has been said about the integration of the systems in Washington, Oregon, and Montana, and on the systems operating over the southern portion of Idaho and Utah. Here, in an area of comparatively great industrial potentialities, power was developed, which in turn helped to develop industry. In the upper central portion of figure 4 is an insert, drawn to scale, showing Great Britain with its 132,000-volt network. Areas containing systems that normally operate in parallel have been marked by cross hatching. Not only is this cross-hatched area highly significant in itself because of the large part of the total area it occupies, but also is particularly interesting in comparison with the area constituting the British Grid. The vastness of the United States, the extent to which netting has

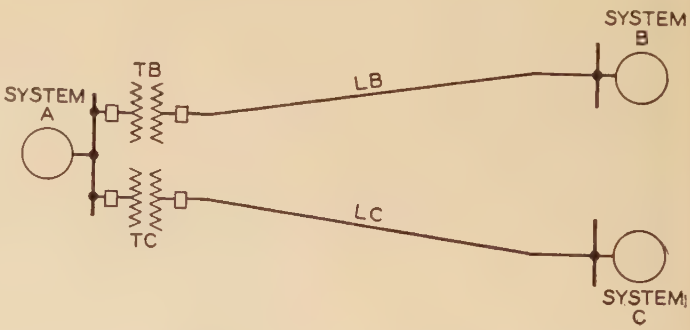

Figure 2. Diagram of a poor type of interconnection between two power systems, in which the maximum power transfer between the systems is limited by a double voltage drop in the impedances of the transformer banks and by the thermal characteristics of the transformers

progressed, and the large areas covered by single networks, spreading in one case to approximately 450,000 square miles, are graphically realized from even a cursory study of this figure.

Some gaps still exist in the integration picture in this country. Reference to figure 4 shows that in some places interconnections actually exist between adjacent large areas in each of which the systems are fully interconnected and continuously operating in parallel. In some places

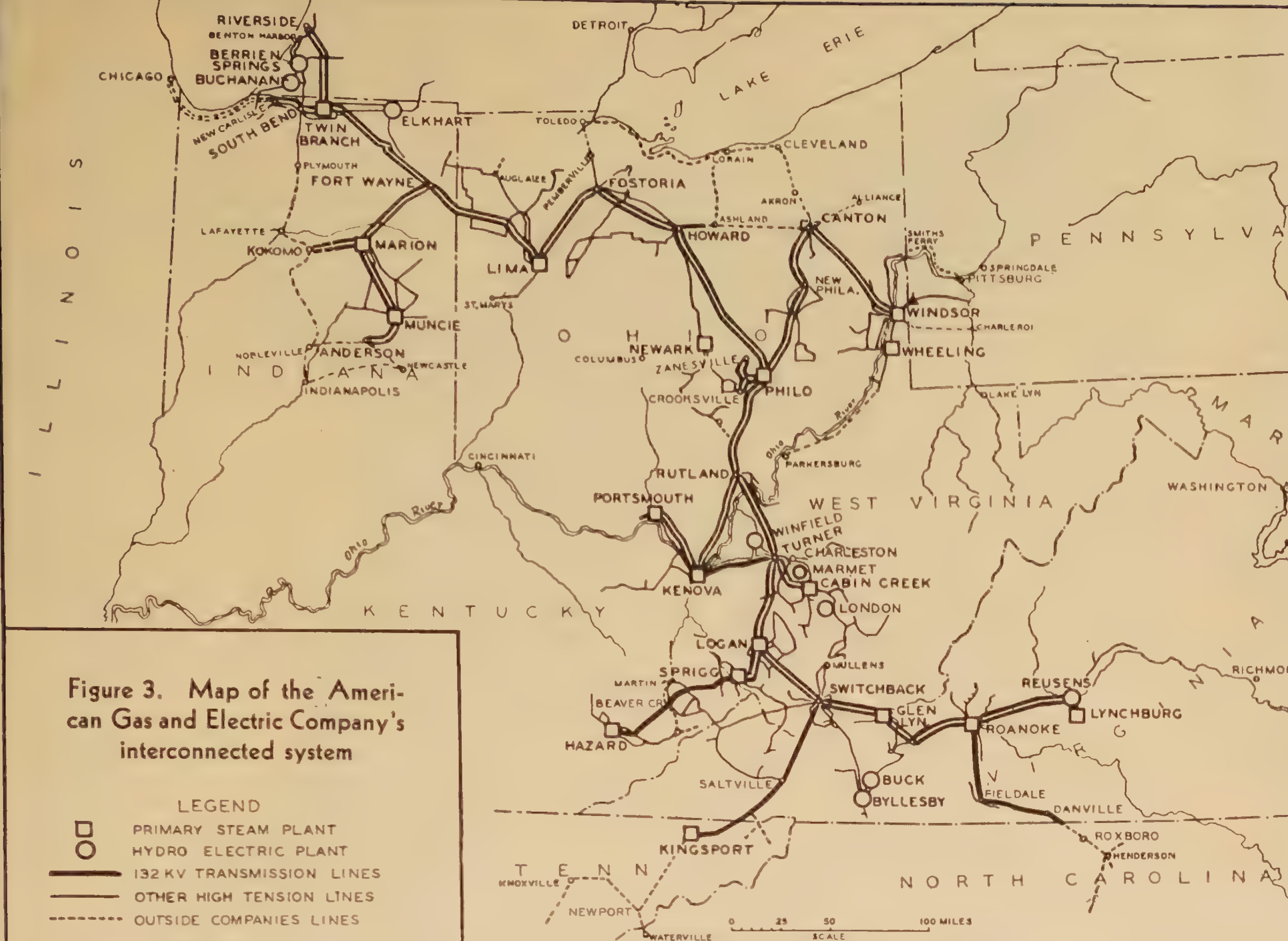

Figure 3. Map of the American Gas and Electric Company's interconnected system

these cross-regional lines provide for all the feasible economies or service protection between areas. In other places, where no ties or weak ties exist, new ties undoubtedly will be made or existing ties will be strengthened as system economics permit. Then, too, there are many places within integrated areas where tie lines eventually will be made heavier or additional ties will be built.

Figure 3 is an example of the integration of individual companies and of companies under the same management; however, in order to obtain the fullest benefits of integration, co-ordination between integrated groups is necessary. In considering a few specific examples figure 5 illustrates the development of co-ordination between the various integrated groups serving the east central and southeastern sections of the United States. This group serves portions of 14 states and covers an area of some 450,000 square miles; it includes a population of roughly 40,000,000. Figure 5 shows also the network of high-tension transmission lines extending over it. The area covered is about 6.7 times the area served by the British Grid, but the population served is only approximately 84 per cent of that served by the British Grid. In December 1936, this interconnected group, operating in parallel, had a simultaneous peak of slightly more than 6,000,000 kw. The combined load curve on that day is shown in figure 6. This is an astonishingly large amount of capacity in parallel and probably is the largest capacity of systems operating continuously in parallel anywhere.

In the northern section of this integrated system steam generation predominates, but in the southern states hydroelectric plants are the chief source of power; moreover, there is a difference in the load characteristics of the various parts of the system. The Chicago area, for example, has a very sharp evening peak during the winter months, but most of the other areas have a peak during the morning. This is typical of industrial areas in the United States.

The interconnection with the Chicago area is through the Indiana & Michigan Electric Company, which is one of the subsidiaries of the American Gas and Electric Company. That company, operating in northern Indiana and Michigan, is interconnected directly with the Northern Indiana Public Service Company, which in turn is interconnected with the Commonwealth Edison Company operating in Chicago. The diversity characteristic between these two areas is particularly striking; the interconnected system of the American Gas and Electric Company has the morning peak characteristic and the Chicago area system has the sharp evening peak. Figure

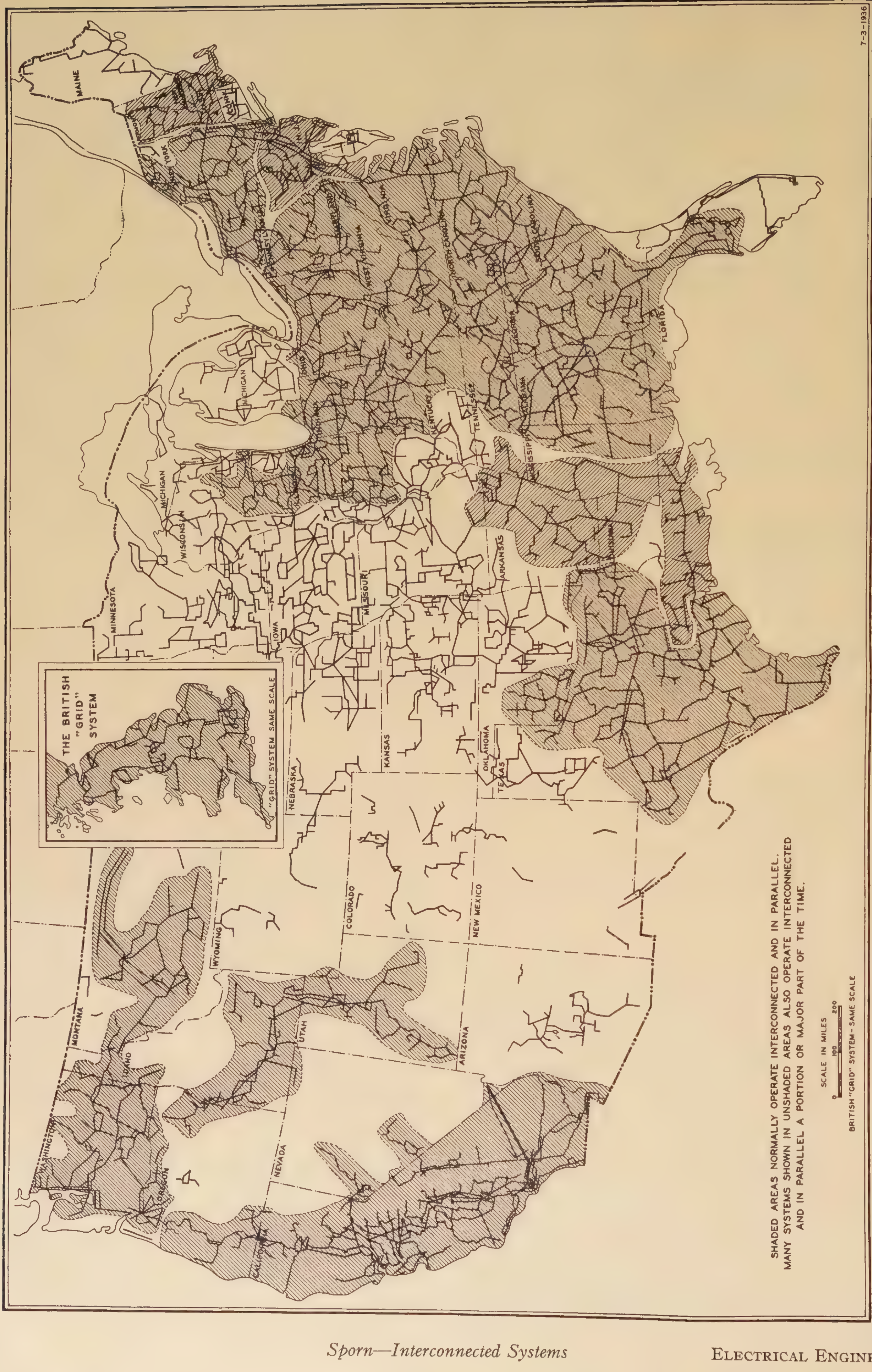

Figure 4. Map showing major electric transmission networks in the United States and a comparison with the size of the British "Grid"

Figure 5. Map showing co-ordinated integrated systems serving the middle eastern and southeastern portions of the United States. These systems normally operate interconnected and in parallel

7 shows this characteristic clearly. During the past five years interchange schedules between the two groups have been established and used, in order to take the maximum advantage of this diversity. Besides the specific gains involved in diversity interchange, the improvement of the technique of operating interconnected systems between two such large areas has been of great value during periods of emergency. During such times a flow of 50,000 kw

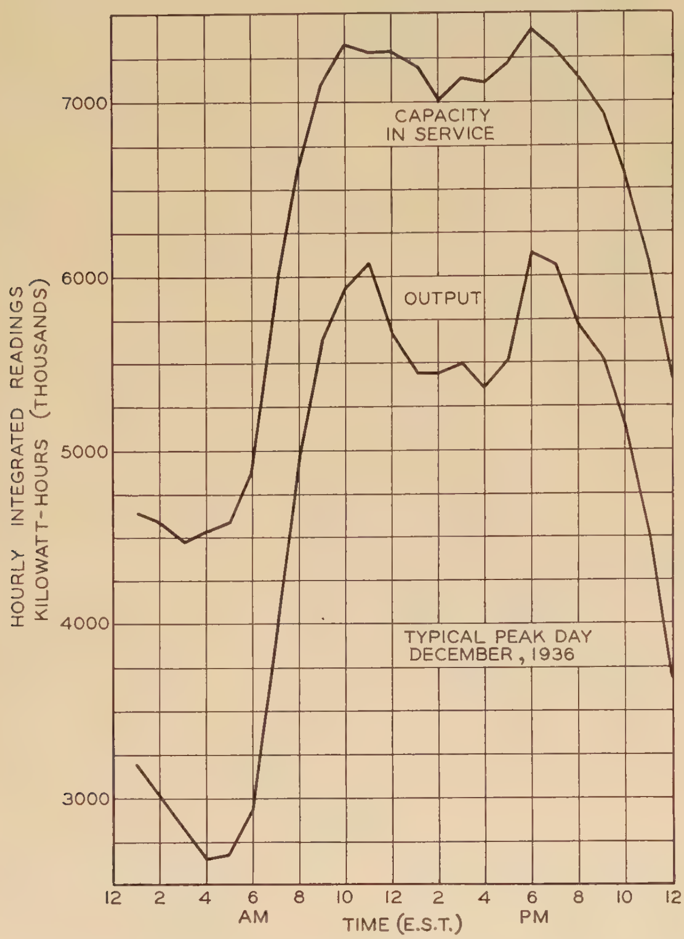

Figure 6. Chart of the combined daily load of interconnected systems that normally operate in parallel and serve the middle eastern and southeastern portions of the United States

in one direction has been reversed and converted into an 80,000-kw flow in the other direction.

The mutual benefits derived from the operation of interconnected systems around Chicago and Indiana are evident to some degree in the group as a whole. Thus the members of the entire interconnected group operate in parallel continuously, with very minor exceptions, and participate fully in the savings and protection of service to consumers that can be made to result from closely co-ordinated operation of interconnected systems. Such savings proceed from the replacement of steam with water power, steam economy interchange, diversity interchange, reduction in reserve generating capacity, and staggering of construction of general facilities.

What Can Be Accomplished by Interconnection

The theoretical benefits of operating interconnected systems presumably are so well-known that detailed discussion is unnecessary. Basically they include the possibility of centralizing generation at economical locations and in plants and units of economical size; the reduction of operating reserve; the participation in diversity advantages; the staggering of construction between parts of a system or between different systems; the more efficient utilization of existing generating facilities; and most important of all, the supplying of help in an emergency. All these are splendid. But they are terms—nothing but words. And instead of defining them by more words, some definite examples of new things that have been done by and through interconnection during the last two years are preferable.

The benefits of diversity interchange derived from interconnection between the American Gas and Electric Company system and the Chicago area continued during the entire period of the depression and are continuing today. But there have been even more striking savings. As the United States started to climb out of the depression, electric loads were growing rapidly and although the American Gas and Electric Company had authorized plant extensions, it nevertheless appeared that before these extensions were completed the generating capacity might become inadequate. Since interconnection facilities were available, the company arranged to obtain the needed capacity from the Chicago area by a short-term contract providing immediately the capacity needed until new generating capacity could be provided; this was arranged without interference with diversity schedules. Whenever the additional generating capacity becomes available this procedure may be reversed if there is any occasion for it. This is a practical demonstration of staggering construction of generating facilities.

For about 15 years the system of The Ohio Power Company has been interconnected with the systems of the Ohio Public Service Company and the Toledo Edison Company. Figure 8 shows the details of this interconnection. The physical interconnection between the two groups is at three points and through four different interconnected lines, two of them at 132,000 volts and two at 66,000 volts. For many years prior to 1930, a system of displacement interchange was in effect, under which Toledo delivered power into the northwest district of The Ohio Power Company, and Ohio Public Service received a corresponding amount of power in the neighborhood of Massillon and Canton, Ohio. During the depression the difference in generation costs between the Philo and Toledo plants, owing to the more expensive fuel at Toledo, was used to advantage in effecting an economy interchange. As much as 10,000,000 kilowatt-hours per month was exchanged, with substantial savings to each group. This interchange and the amount of mutual help in emergency was limited, however, by the 66-kv connection and the two intervening transformations connecting the Ohio Power system with Toledo.

As loads began to increase and the idle generating capacity began to be placed in service, the Toledo and Ohio Public Service Companies were faced with the problem of increasing their system capacity. Their studies indicated that an additional unit should be placed in the Warren plant to meet the load requirements in that area. Joint studies with The Ohio Power Company indicated, however, the economy of placing the generating unit at Toledo instead of Warren and strengthening the interconnection between the Toledo and The Ohio Power Company systems by building a 132-kv tie between them. To make it possible for the Ohio Public Service Company to meet its load area requirements in the territory of the Warren plant, The Ohio Power Company agreed to furnish energy at Canton from Philo. Toledo and Ohio Public Service Company jointly agreed to return this energy at Fostoria, where The Ohio Power Company needed it, over the new Toledo-Fostoria line. This accomplished several things: It strengthened the interconnections between the three companies; it gave the Ohio Public Service Company the necessary capacity on the eastern section of its system; it made available another necessary source of supply to the northwest section of The Ohio Power Company; and it paved the way for economy interchange between The Ohio Power Company and the other two systems in greater volume. This is an excellent example of co-ordinated development of two power systems, under different management.

All of these, and many others could be cited, are without a doubt splendid examples of what can be done by any power group applying itself intensely to the solution of a technical and economic problem as difficult as interconnection. They particularly reveal the soundness of interconnection from an investment standpoint, if the plans and ideas are carefully executed. A utility has a double duty: a duty to the public for which it provides facilities; and a duty to its bondholders and stockholders, whose money provides the necessary facilities to proceed with no improvement unless it is sound. It cannot, for example, and has no right, to indulge in any grandiose schemes of interconnection because they fit so well into a preconceived paper picture of how a group of systems should be co-ordinated. Nevertheless, one must recognize that too narrow a view frequently will fail to disclose all the potentialities of a situation. Frequently the immediate benefit from an interconnection does not compare in value or significance with the system benefits obtainable under extraordinary emergencies. Some examples of the achievements of interconnection on the American Gas and Electric Company's system during the last two years will demonstrate this more clearly.

In March 1936, the entire Ohio River Valley, especially in the upper region, was subjected to a severe flood. At Pittsburgh, where the flood stage was about five feet above the all-time record of 41 feet in 1763, all the major power plants were forced to suspend operation, and this was true of the entire upper valley region. During this time interconnection enabled The Ohio Power Company to supply the facilities of the entire Windsor plant, (which stood up, and which is jointly owned by the West

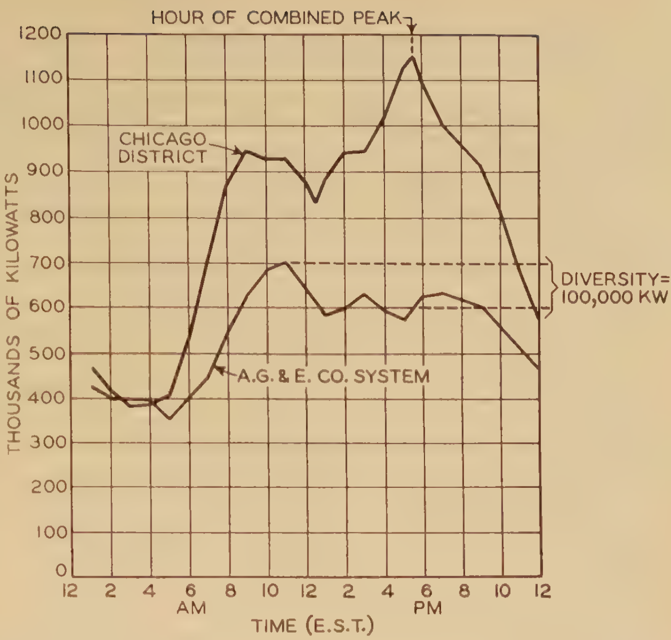

Figure 7. Daily load curves showing diversity between Indiana and Chicago (Ill.) areas

Penn Power Company) to the West Penn Power Company to replace the capacity lost by this and other interconnected companies. Additional power was fed to the stricken area by The Ohio Power Company through its interconnections at Canton with the Ohio Public Service Company and the Ohio Edison Company. At the same time other companies interconnected with The Ohio Power Company stood ready to furnish additional capacity up to 100,000 kw. Although the American Gas and Electric Company lost no plants on its own interconnected system, some of the areas supplied by the system were hard struck by the floods, but the system was able to maintain full service in those areas and to furnish all the help needed by the interconnected companies.

In January 1937, another flood occurred in the Ohio Valley, but this time, although the upper region was not seriously affected, the flood in the lower valley region was unprecedented. The sections around Huntington, W. Va., Ashland, Ky., and Portsmouth and Ironton, Ohio, were particularly hard struck by the flood, requiring discontinuance of generation in the 40,000-kw plant at Kenova (near Huntington, W. Va.), which normally serves this local area. However, as a result of strong interconnections with other parts of the system, service was available at all of these points. Farther down the river at Cincinnati, all power plants were out of commission and the American Gas and Electric companies were part of an interconnected group that supplied power to Cincinnati during this emergency.

In July 1935, the 85,000-kw Glenlyn plant in Virginia suddenly was put out of service by a local cloudburst, and about 100 men worked for a week to get the plant running again. In the meantime customers in that area were not affected in any way, since strong interconnections with other parts of the system mantained continuity of service without the Glenlyn plant.

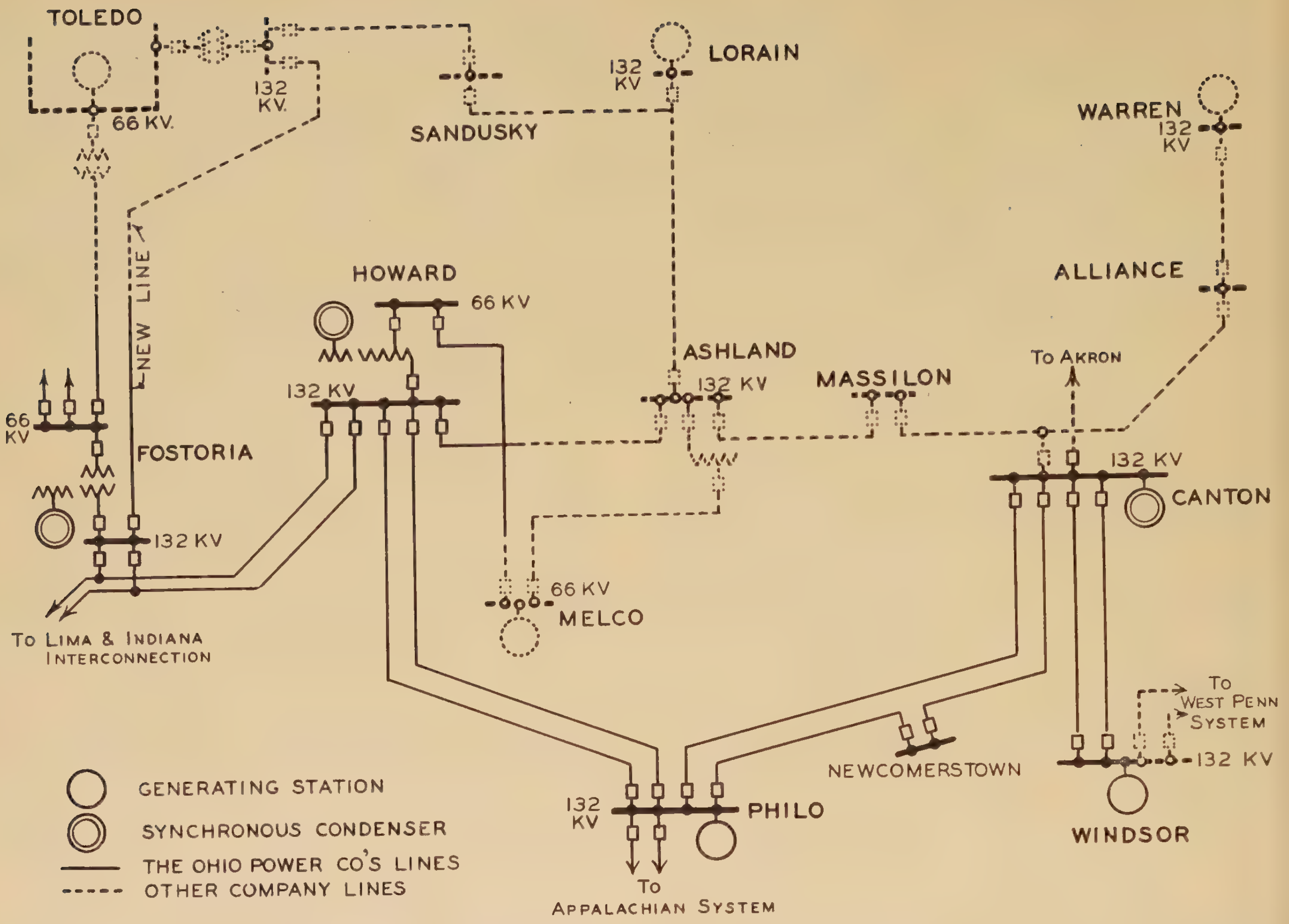

Figure 8. Diagram of the interconnection embracing The Ohio Power Company, Ohio Public Service Company, and Toledo Edison Company

During the flood of March 1936, the Susquehanna River reached a flood stage that was the highest on record since 1846. On March 13 the river reached an elevation of approximately 555 feet, or 25 feet above normal at Stanton plant. The plant maintained service during this period without trouble, and the river then receded; but on March 16 the river again began to rise in consequence of further heavy rains over the entire watershed. During the following day the river started to rise very rapidly and by 9:30 a.m., March 18, the river elevation was 556 feet, $3^1/_2$ inches, which was 1 foot, $3^1/_2$ inches above the basement floor level. The entire yard surrounding the station was flooded and barricades were placed around all doors and other openings where water was finding its way into the building. The water level was beginning to rise and it was found impossible to barricade the building sufficiently to keep the plant in operation. It was then decided that number 2 unit should be taken out of service to permit the removal of motors from the lower levels to prevent flooding of the windings. At 11:58 a.m. the river elevation, 557 feet, 1 inch, was still rising, and so much water was coming into the building that the pumps were overloaded and the boiler-room basement and ash pits began to fill up. Number 1 unit then was immediately taken out of service and the operators were ordered out of the lower stations in the building to prevent loss of life. Power was shut off in the flooded area to prevent damage to electrical equipment. A hot-well pump motor from each generating unit was removed to a higher level and the motor of one circulating pump was removed from the pump room. At the time the men were removed from the pump room they were working $38^1/_2$ feet below the level of the river.

Number 2 unit was taken out of service at 10:30 a.m. on March 18, and was out of service until 6:45 a.m., March 30, or a total outage of 284 hours and 15 minutes. Number 1 unit was taken out of service at 12:02 p.m. on March 18, and it was out of service for a total of 259 hours and 28 minutes before it could be placed back in service. This unit actually was not placed back in service previously because it had been scheduled for the annual overhaul.

During this time interconnections with the Pennsylvania Power & Light Company were maintained. During the Stanton outage the Suburban plant, normally a stand-by plant, was operated at its full capacity of 50,000 kw. On some days during the day peak a small amount of help from the Pennsylvania Power & Light Company was necessary, but during off-peak hours Suburban was operated and energy was fed back to Pennsylvania Power

& Light Company. But the important point is that continuous service was maintained throughout the entire period. Although some assistance was required at times, during other periods when the system load was less than normal the neighboring systems could be aided. The Binghamton territory also suffered from heavy floods and all of the generating equipment in that territory was out of service. The interconnection between Peckville and Binghamton was operative during this entire period and the Scranton Electric Company supplied Binghamton throughout the flood period.

In each of these emergencies interconnection came through with flying colors and saved the service, because the interconnections were not half-hearted and because the systems had been operated for years with that end in view. Moreover, interconnection was in the front rank of the forces sustaining dozens of communities that otherwise would have had added to the normal ravages of a flood the misery and great danger to life and property following the loss of electric service.

These experiences have been matched by dozens of similar experiences on other systems, but the author purposely has limited the examples to the range of his own experience. Nevertheless, all of them prove that by developing the idea and consistently following the theory of operating systems interconnected, capital and operating economies may be made possible; some provision against catastrophies may be made, and service may be maintained under emergency conditions frequently not even envisioned.

In all of this no long distance transmission of power is involved. Those who have studied the problem of transmission closely, and who thoroughly understand the economics of power supply, know that there is no sound economics in long-distance transmission of power. On the American Gas and Electric Company system, for example, the actual mean weighted distance of transmission under normal conditions in the nine states over which the system extends is less than 60 miles. The economies pointed out were accomplished, therefore, without doing violence to that fundamental of relatively short transmission distance. Further, these examples emphasize an important principle of sound system planning: that after having provided against almost every conceivable emergency in operation and in the great responsibility of operating a utility system, to provide against contingencies wholly inconceivable and unpredictable sometimes is highly desirable and often necessary. This, in general, can be provided economically only by interconnection.

The reader must not believe that the solution of the interconnection problem has been simple. There were, and there still are, a great many difficulties involved in working out interconnection problems, and a great deal of time and effort still is being spent on many of these problems: for example, the problem of frequency and load control, the lightning problem, the relaying problem, and the problem of stability. But the important thing to remember is that, difficult as it has been, the broad interconnection problem has not been shirked because of technical difficulties. It has been carried forward because through the proper application of interconnection and co-ordination electric utility companies have been able to provide better service, cheaper service, better-protected service, and even safer investment. Above all and under all conditions they have been able to get the satisfaction and the peace of mind that come from a definite knowledge that the utmost that can be done by a progressive art and by the intelligent application of capital has been done to assure a proper discharge of the responsibility assumed in undertaking to render utility service. And that this responsibility has been discharged by the utilities of the country in general is a fact that is known to power system engineers the world over.

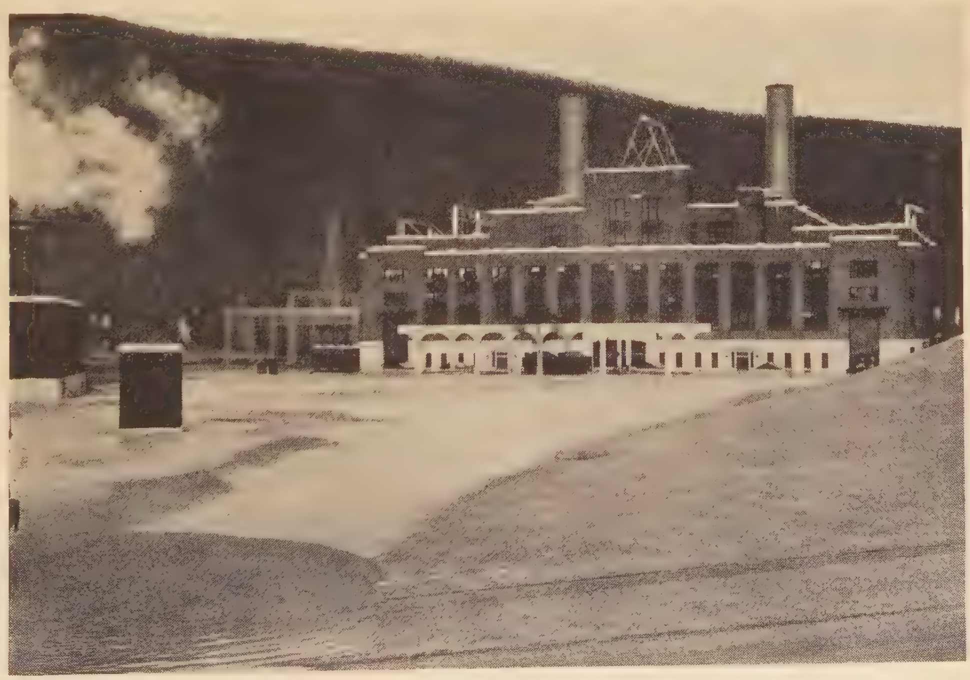

Figure 9. During the flood of March 1936, along the Susquehanna River the water reached the highest flood stage recorded at any time since 1846. The Stanton plant, situated near West Pittston, Pa., was badly flooded, as shown here, and was forced out of service. Service was maintained in the area served by the Stanton plant by other plants in the interconnected system

Electron Theory

By R. G. KLOEFFLER
FELLOW AIEE

A brief and simple picture of electron theory, this article is intended for those readers who are not familiar with the more recent theories and who have followed branches of the profession not dealing with electronic devices. The electron is shown to be part of the atom, and to be the means by which electricity flows. Its function in electron tubes is explained, and the operation of amplifiers, rectifiers, and photoelectric cells of various types is discussed.

THE DISCOVERY of the electron dates back to the beginning of the present century. This important event was foreshadowed by many early experiments and theories. In 1725, DuFay discovered that the gaseous region around a red-hot body would conduct electricity. In 1879, Crookes found that the rays in his experimental tubes were negatively charged particles. Edison's experiments with the incandescent lamp led to the discovery in 1883 that an electric current did flow from an incandescent filament to a plate in a vacuum but that it would flow in only one direction. This is known as the Edison effect. J. J. Thomson is generally given credit for the discovery of the electron because of his experiments and reports to the scientific world in a period shortly before and after the year 1900. He developed a very ingenious method for measuring the charge on the ion and secured an approximate value of the magnitude of that charge. Wilson and other scientists made some improvements on Thomson's method and secured other approximate values for the magnitude of the charge of the electron. It remained for an American physicist, Robert Millikan, to make further refinements in the method of measuring the magnitude of the charge and thereby secure results announced to the world in 1913 which were absolutely convincing as to the existence of and the value of that fundamental electrical charge on the electron. This electron was a minute indivisible negative charge of electricity having a very small mass. The term electron has always been associated with the negative charge while the term positive electron has been associated with another complimentary unit, the proton.

Four years ago a cosmic-ray photograph taken at the Norman Bridge Laboratory showed unmistakable evidence of the track of a particle having the same mass and the same magnitude as the charge on the electron but of the opposite sign. Thus was discovered the true positive electron, or what is often termed the positron. This recent discovery of the positron has raised many questions in the scientific mind and has tended to upset some of our well-accepted theories regarding matter.

Nature of Electricity

The scientific world has offered many theories regarding the nature of electricity. Benjamin Franklin's single-fluid theory was one of the first. His theory pictured a colorless, weightless, invisible fluid or "electrical fire" which could permeate all matter. A normal amount of this fluid caused a body to be neutral, an excess amount produced a positive charge, while a deficiency gave rise to a negative charge. Later theories were offered by Faraday, Maxwell, and others. It remained for the discovery of the electron to give a definite basis for theories and conceptions which would come nearer to satisfying the inquiring mind of man. Up until 1910 or later, it was generally conceded that no one knew anything of the nature of electricity, though men understood quite well many of the characteristics, properties, and laws of magnetism, electric charges, and electric currents. The general acceptance of the electron gave rise to new theories and conceptions in the fields of chemistry, physics, and electricity. The molecule had been long considered the smallest divisible part of matter, the atom the smallest division of an element, and now the electron, an indivisible and fundamental electric charge, a mere speck of electricity, became a part of the atom. Science gave the electron a mate, a proton, or a positively charged particle having the same charge as the electron but a mass 1,834 times as large. Then these two fundamental building blocks, the electron and the proton, became the basis of all chemical elements. The difference between the elements was determined by the number of pairs (electron and proton) going to constitute the atom. Bohr furnished a mechanical model or picture to show the structure of the building blocks within the atom. This model (figure 1) envisions a structure like a small solar system having a nucleus surrounded by one or more particles moving in orbits. The nucleus has a positive charge and contains all of the protons in the atom. It may also contain a part of the electrons, with the remainder of the electrons moving in orbits about this nucleus. The hydrogen atom has the simplest structure. It consists of a single proton constituting the nucleus with a single electron revolving in a surrounding orbit (figure 2).

To get a conception of the relative physical size of this hydrogen atom, all parts of the atom may be imagined to be expanded until the nucleus, which is the proton, has the diameter of a baseball and is placed in Dallas, Texas. Then the lone planetary electron will revolve in an orbit which passes through New York City and San

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Francisco, and the size of this expanded electron will be 300 feet in diameter, or about big enough to rest comfortably in a football stadium or a baseball park. This picture shows the relatively "big hole" or empty space in an atom and explains why some electrons and atomic particles may be projected through many atoms before being stopped.

In order to explain radiation phenomena, Bohr assumed that there are a number of possible orbits in which the revolving electrons may move and that the jumping of

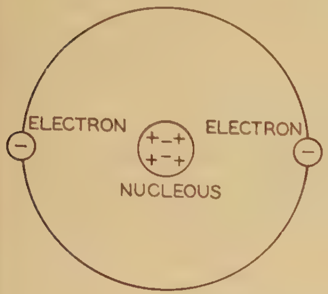


Figure 1. Structure of the atom according to Bohr

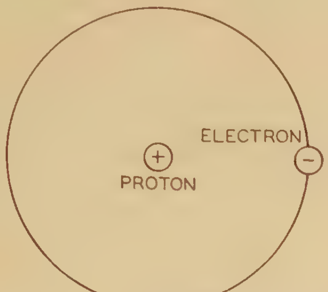


Figure 2. Structure of the hydrogen atom

the electron from one orbit to another is due to the absorption or radiation of energy. Consequently, the orbits are often referred to as energy levels. The orbits are pictured as circles or ellipses and usually as a combination of both in order to explain various atomic phenomena.

At the time when many electrical engineers were in the college classroom, teachers did not attempt to give any physical conception of the phenomenon of electricity or of the units of measurement which were employed. The scientist, the teacher, and the student of former days accepted electrical phenomena as a matter of fact, and, in common with the layman, said, "We do not know anything of the nature of electricity." Today there are some conceptions which have arisen from the discovery and measurements of the electron and from our pictures of atomic structure. Thus, to take the case of the phenomenon of attraction and repulsion of charged bodies, a positively charged body is one in which a large number of electrons have been removed from the body so that the total number of positively charged protons exceeds the number of electrons present. Thus the body has a strong attraction for electrons and it is said to be positively charged. In like manner, a negatively charged body has an excess of electrons above protons and this body exerts a strong attraction for protons, an excess of which may be found in a positively charged body.

Electric Currents

Two bodies oppositely charged have a difference of potential between them. A difference of potential or voltage is measured by the work required to carry a unit positive charge from one body to another against the force of attraction or repulsion. The magnitude of the difference of potential depends upon the concentration of the charge and not on the amount of the charge. Thus an excess of a billion electrons on a sphere ten centimeters in diameter would have only one-tenth as much potential as it would have if concentrated on a sphere one centimeter in diameter. The 110 volts at the ends of a lighting circuit are due to an enormous concentration of electrons along one wire and a corresponding deficiency in the other. When a human being contacts this circuit, the excess of electrons in one wire attempts to pass through the body to the other wire with a result well understood as far as one's feeling is concerned.

If a positively charged and a negatively charged body are brought in contact, electrons from the body with negative charge (excess of electrons) will move over to the body having the positive charge (deficiency of electrons) until an equilibrium of charge has taken place. This transfer of electrons from one body to another constitutes an electric current. Thus we can picture the phenomenon of electric current as a transfer or co-ordinated movement of electrons along a path or circuit. The protons do not move in solids because their mass is 1,834 times as great as the electron, and because of their firm attachment to the atom itself. The magnitude of an electric current is determined by the number of electrons which pass a given point in a circuit per unit of time. To produce an electric current of one ampere, 6.3×10^{18} electrons must pass a point in one second. The individual electrons may move along the circuit slowly or quickly. Thus in a high-voltage vacuum tube, the electrons may move with a velocity approaching that of light, whereas in another part of the circuit they may drift along at a "snail's pace" of only a fraction of a centimeter per second.

The direction of the movement of electrons in an electric circuit is opposite to the conventional direction of current as adopted by scientists many years ago. Thus the early choice of direction of current was unfortunate in that it complicates conceptions and explanations in electronic devices. All remarks in this discussion will pertain to the direction of electron movement.

Current Flow in Solids and Liquids

An electric current in a solid is due to the movement of "free" electrons along that solid. The "free" electrons are not "extras" or those electrons above the normal number to balance the protons, but rather electrons which at certain instants are free from their parent atom to be moved on to another atom in a sort of relay race. Although the molecules are close together within a metallic solid, they do have a movement due to thermal kinetic energy and this movement increases with the temperature. The electrons, in turn, have a movement about their nuclei and at certain positions, due to the molecular action and the electron action, the electrons may become as close to the nuclei of other atoms as their parent. At that instant the urge resulting from a difference of potential can easily move these free electrons along the circuit.

The passage of an electric current through a liquid is easily understood on the basis of the electron theory.

Distilled water is practically an insulator but when an acid or base is added to the water, it becomes a conductor. It appears that part of the molecules of the added material automatically disassociate into fragments or ions. Thus hydrochloric acid separates into $H+$ and $Cl-$ and sodium chloride into $Na+$ and $Cl-$. This means that the H and Na atoms constituting the positive ion have lost one electron and are positively charged. In a similar manner, the Cl atom has an additional electron and carries a negative charge. If a difference of potential is applied to electrodes in the solution, the negative ions will travel to the positive electrode and give up an electron. In like manner, the positive ion will travel to the negative electrode and take on an electron. Thus the ions serve as carriers to convey electrons through the solution and this movement of electrons constitues the electric current.

Current Flow in Gases

Conduction of electricity through gases is produced through the medium of ions as in a liquid but the ions are produced in a different manner. Gas ions may result from the bombardment of gas atoms by high-speed electrons or ions, and by the action of electromagnetic waves of suitable frequency. If a high-speed electron is projected into a gas, it will collide with some of the molecules of that gas. The collision usually occurs with the electrons in the outer orbits of gas atoms. The result may be merely the change of direction of the flying electron or it may be the actual removal of an electron from the outer orbit of the gas atom. When the disruption of the atom takes place, the remaining part of the atom has lost an electron, is positively charged, and is called a positive ion. The electron which is removed may remain a free electron and as such it is a negative ion. It may join another neutral atom and thus form a negative ion of a different kind as far as mass is concerned.

The two gas ions formed by the bombardment of a single electron will move to electrodes having a difference of potential and placed within that gas. In transit to the electrodes these gas ions will collide with other gas molecules and if the difference of potential is sufficiently high and other conditions favorable, these collisions will result in the production of other gas ions. The latter ions may likewise produce still others while in transit to their respective electrodes. Thus ionization of a gas becomes somewhat accumulative in action and fairly large currents may result.

The collisions of electrons and ions with atoms are probably not physical contacts as when a baseball bat hits a ball, but rather the repulsion between the charges on the individual electrons and ions. The molecules of a gas are in a constant state of violent motion and the electrons, in turn, are moving about in their respective orbits. It can readily happen that the relative directions of motion of the electrons are such that an electron is caused to leave its parent atom and produce ions.

An interesting by-product of ionization occurs when a colliding electron does not have sufficient velocity to produce ionization but does cause an electron in an outer orbit to jump to another orbit of higher energy level. The energy absorbed by this change of orbit is released in the form of a visible electromagnetic wave as soon as the electron drops back into its original orbit. The visible radiation or light is of a color characteristic of the element constituting the gas molecule. Frequently the light is monochromatic. This principle of light production underlies all of the gaseous and vapor electric illuminating sources such as the neon, mercury-vapor, and sodium-vapor lamps.

Resistance to Current Flow

Electric resistance is that property of a circuit which opposes the passage of a current. It is easily explained on the basis of the electron theory. In a solid conductor resistance is due to the collision of the electrons which constitute the current with the atoms and molecules of that solid. The magnitude of the resistance depends on the number of free electrons available. In a similar manner, the resistance of an electrolyte or gas is determined by the number of ions produced and by the number of collisions between the moving ions and the molecules present. The influence of temperature on resistance is readily explained. In a pure metal a rise in temperature increases the kinetic thermal energy, speeds up the motion of the molecules, and hence tends to increase the number and the violence of the collisions, thus increasing the resistance.

It is of interest to note that the "hither and yon" movement of free electrons in solids does produce infinitesimal differences of potentials or voltages at the ends of conductors. These minute voltages introduce noise termed "resistance noise" in high-gain amplifiers and limit the smallness of signals which can be amplified satisfactorily.

Electronic Devices

The first electronic device was the two-electrode tube patented by Fleming in 1903 and known for several years as the Fleming valve. It took the place of the coherer as a detector of wireless telegraph signals. This device has grown to be the detector and the rectifier of our modern electronic application. DeForest added a third electrode or grid to the Fleming valve and patented the three-electrode tube in 1907. For many years it was known as the DeForest audion. This device was primarily an amplifier of electric current, and it constitutes one of the greatest inventions of this century.

Freeing Electrons From Solids

The operation of most electronic devices depends upon the removal of electrons from solids in some manner. One method for removal is accomplished by impact on the solid of an electron, an ion, or the nucleus of an atom. A violent impact may splash electrons from the outer orbits of atoms lying in the surface of the metal. Electrons splashed out in this manner are known as delta rays.

Electrons may also be "brushed out" or released from

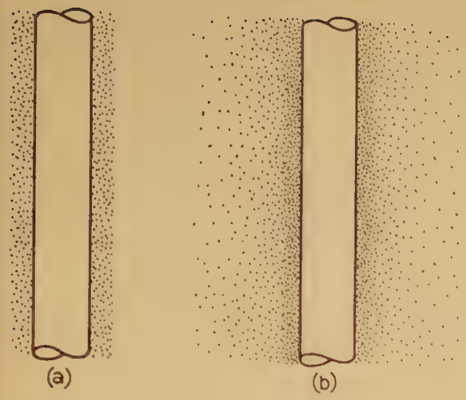


Figure 3. Emission of electrons from a heated body

a few sensitive substances by the impinging of electro-magnetic radiations of suitable frequency. The electro-magnetic radiations are light waves, either visible or invisible. This phenomenon of electron removal forms the basis of action in photoelectric cells.

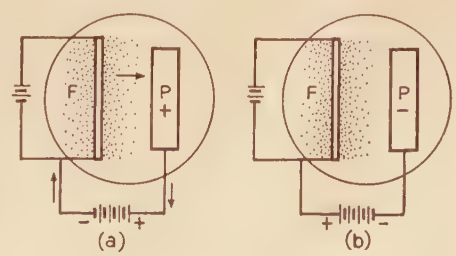
A third method for the removal of electrons from solids is through the application of heat. This method is known by the term thermionic emission and is used in millions of electron tubes of today. The nature of this emission is not difficult to visualize. The electrons are bound to the atoms by their attraction for the nucleus. The electrons are bound to the molecules and to the substance of which they are a part by an attraction called electron affinity and the energy required to remove an electron from a substance is termed the work function. The molecules are in a constant state of agitation while the electrons, in turn, are moving about in the orbits of the atoms. The kinetic agitation of the molecules rises with the temperature and at a sufficiently high temperature the velocity of motion of a few electrons may become great enough to break through the surface of the solid. This escape of the electron is called emission and it may be pictured as in figure 3. Part *a* shows the emission at a relatively low temperature. At the higher temperature a cloud or atmosphere of electrons emanates or evaporates from the hot filament or cathode as shown in part *b*. When the electrons are hurled forth by their kinetic energy, they give to the cathode an image positive charge which exerts a force of attraction. Thus as soon as the electron breaks through the surface, it is attracted back and, barring the presence of other fields and forces, it drops back into the cathode. Electron emission was studied by Richardson who reasoned that it was similar to the phenomenon of evaporation of liquids. Richardson suggested an equation now bearing his name for showing the magnitude of current emitted.

The materials used for cathodes which are satisfactory for electron emission are tungsten, thoriated tungsten, and oxide-coated alloys. Pure tungsten cathodes operate at a high temperature; they are strong and will withstand positive-ion bombardment better than the other emitters. The thoriated-tungsten cathode was developed by Langmuir and his co-workers. It consists of tungsten containing a small amount of thorium oxide. At a suitably high temperature the oxide is reduced to thorium which diffuses through the metal and forms a layer of pure thorium on the surface of the cathode. The thorium layer, one atom thick is the source of electron emission. Wehnelt found that certain oxides when placed on a metal base became excellent emitters at relatively low temperatures. Strontium and barium oxides have proved to be the best. During operation a thin layer of barium forms on the surface of the oxide and this serves as the source of emission of electrons.

Action of Electron Tubes

The value of nearly all electron tubes lies in their property of unilateral conductivity (that is, the ability to conduct current in one direction but not in the other). This property was shown in the "Edison effect" and was the basis of action of the Fleming valve. The reason for this property can be readily understood. Consider two electrodes placed in a tube having a high vacuum as shown in figure 4. Let F represent the cathode which is heated so as to be emitting a copious supply of electrons and P is the anode connected through a battery to the cathode. If the battery is connected so that P is positive with respect to the cathode, as in *a*, the negatively charged electrons will be attracted toward P and part of them will land on P, thus constituting an electric current through the vacuum. However, if the battery be connected so that P is negative with respect to F, as in part *b*, it will repel the electrons and no current will pass. Obviously, if an alternating source of potential be substituted for the battery, electrons will pass to P for those loops of voltage when P is positive but will not do so when P is negative. Thus this two-electrode device becomes a rectifier of alternating current. The factors which control the flow of electrons between the cathode and the anode or plate P are not entirely evident on the surface. Thus the number of electrons which pass to P in a tube having a high vacuum depends first on the initial velocity of emission of the electrons which is determined by the temperature of the cathode; second, upon the attraction of the cathode for the electrons; third, upon the attraction of the plate which depends on the plate voltage; and, fourth, upon the space charge. The fourth factor, space charge, is due to the resultant charge in the space surrounding the cathode caused by the presence of the electrons which are being emitted. A cloud of electrons surrounding a cathode may be pictured as in figure 3. Each of these electrons is a negative charge and as such exerts a repulsion on all other electrons in its vicinity. At the instant a particular electron emerges from the cathode, all electrons in space are exerting a repelling force but as it moves away from the cathode all of those behind it are repelling or now aiding it toward the plate. The influence of space

Figure 4. Diagram of two-electrode tube or diode



charge is very effective in a high vacuum and it was once believed that no emission would exist in a perfect vacuum. The two-electrode high-vacuum tube with tungsten filament is used for rectifying high voltages for use in radio transmitting stations, X-ray equipment, smoke eliminators, and wherever a high continuous voltage is desired. The two-electrode vacuum tube is used as a detector in modern radio receiving sets.

The addition of a small amount of gas to a two-electrode tube changes its characteristic action. The presence of the gas permits ionization to occur and the positive and negative ions thus formed pass to the cathode and anode, respectively. The ions serve as carriers of electrons and increase the current slightly but a large increase in current results from another action. Thus the negative ions formed are electrons and are attracted swiftly to the positive anode. The positive ions are atoms (less one or more electrons) and because of their large mass they move relatively slowly. Each positive ion can neutralize the charge on one electron in the space charge at a given instant, but because of its slow motion it serves to neutralize many electrons while in transit. Thus it is possible for a single positive ion to neutralize successively as many as 300 electrons in the space charge. The neutralization of the space charge permits the positive anode to attract many more emitted electrons and thus the current through the tube is greatly increased.

The gas-filled two-electrode tube is inherently a low-voltage device (that is, it has a low voltage drop from cathode to anode). It rectifies much larger currents than the vacuum type and is used for charging storage batteries and similar low-power d-c applications.

Control of Electron Tubes

DeForest added a third electrode known as the grid to the electron tube. In application in the tube, the grid (figure 5) is a screen or wire mesh placed between the emitter or cathode and the anode or plate. The grid functions by means of a change of potential or charge upon its surface. This change of potential on the grid becomes an additional force acting upon the electrons surrounding the cathode and because of its nearness to the cathode exerts a very powerful influence upon the electron stream to the anode. The figure is a cross-sectional view which shows the usual location of the control grid in a three-electrode tube or triode. If a small positive potential be placed upon the grid, it will exert a relatively powerful pull upon all electrons which emerge from the surface of the cathode. This pull will be added to the effect of their initial velocity of emission and will oppose the repelling effect of space charge. The result of this action is that many electrons will move out farther from the cathode and come under the influence of the positive anode and thus pass to the anode. Any increase in the positive potential of the grid will cause still more of the electrons to move to the plate. Conversely, a small negative potential on the grid will repel every electron that emerges from the cathode and add its weight to the effects of space charge and cathode attraction. Thus many electrons which otherwise would be carried far enough by their

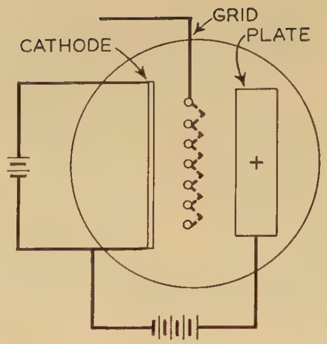


Figure 5. Diagram of three-electrode tube or triode

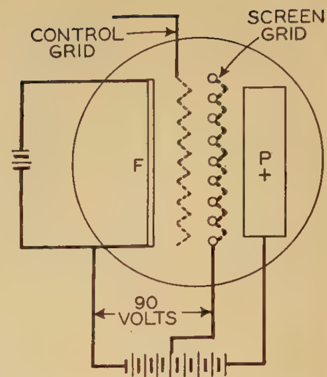


Figure 6. Diagram of four-electrode tube or tetrode

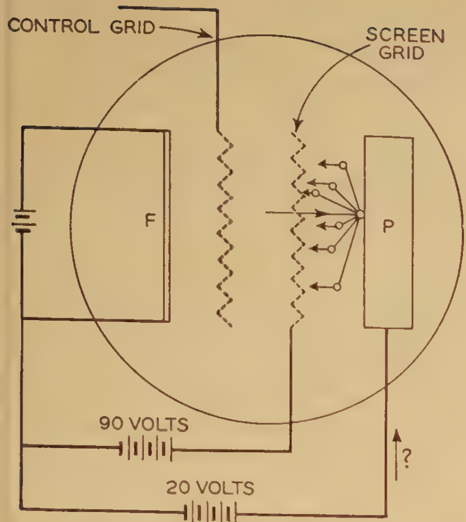
initial velocity of emission to travel to the plate will now be held in check by the repelling force of the negative grid. It is obvious that a sufficiently negative potential on the grid would bar all electrons from ever reaching the anode. Thus it is apparent that a suitable variation of potential placed on the grid will control accurately the flow of current in the cathode-anode circuit. Since a mere change of potential does not involve any expenditure of power we have the strange phenomenon of controlling a large amount of power without the use of any power. In the actual application of the triode or three-electrode tube, the circuit for the grid does use some small amount of power. The triode thus is inherently an amplifier of alternating currents and as such it finds its greatest application.

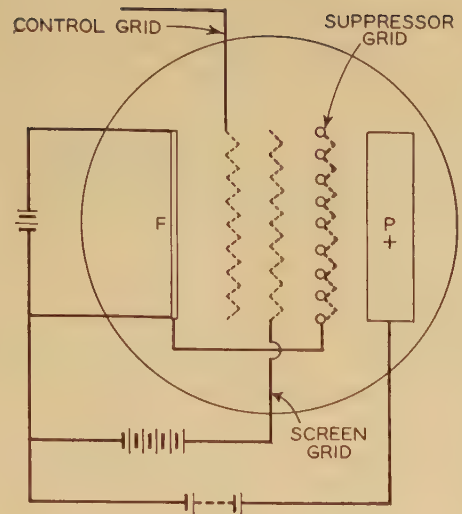
Use of Electron Tubes

Radio signals of telegraph, voice, or television are sent out through space by means of very high-frequency alternating currents called carriers. This method is necessary since lower frequencies will not travel through space very far. The various low-frequency signals to be transmitted are impressed upon the high frequencies by a process of forming, molding, or modulating. At the receiving end of a radio circuit the impressed signals must be demodulated or detected and thus recovered from the high-frequency carrier.

The three-electrode tube or triode is used first as an oscillator in a resonant circuit for producing the high-frequency carrier current. Secondly, this type of tube is used to modulate or mold the low-frequency signal into the high-frequency carrier. In the third place, the triode may be used in the receiver as a detector or remover of the low-frequency signal from the transmitted carrier. Lastly, triodes are used in cascade for amplifying the feeble received signal so that it may be suitable for the desired purpose.

Additional electrodes, usually some type of grid, have been added to the three-electrode tube to increase the range of amplification, to improve the fidelity of amplification, or to prevent oscillations. The heavy loading of a triode by wide fluctuations in the grid potential and the resulting plate current may introduce distortion of the





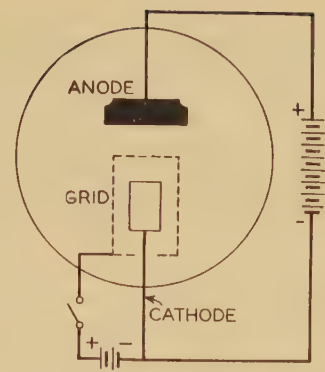


Figure 9. Diagram of a grid-controlled gas-filled rectifier

Figure 7 (left). Secondary emission in a tetrode

Figure 8 (center). Prevention of secondary emission by fifth electrode in a pentode

amplified signal and may produce oscillations because of the feedback of the grid-plate capacitance. To reduce such undesirable results, a fourth electrode known as a screen grid may be introduced between the control grid and the plate, as shown in figure 6. This screen grid is connected to a source giving it a fixed potential somewhat under the normal plate voltage. The screen then serves to establish a fixed potential in space giving a constant attraction upon all emitted electrons regardless of any variation of plate voltage and it greatly reduces the grid-plate capacitance.

A curious phenomenon may result in the use of the screen-grid tube if a low plate voltage be encountered. Thus, at all positive values of plate voltage above 10 to 20 volts, the electrons hitting the plate produce secondary emission (splash out electrons from the plate). In the triode these electrons of secondary emission are attracted back to the plate but in the screen-grid tube for a certain range of low values of plate potential, the splashed-out electrons are attracted back to the screen grid (figure 7). In special cases it is possible for more electrons of secondary emission to go to the screen grid than there are electrons arriving at the plate. Under this condition the plate current will reverse or become negative. Even though the plate current does not reverse, the electrons of secondary emission, which pass to the screen grid, do introduce distortion in the tube when used as an amplifier under the conditions assumed. To prevent this phenomenon, which occurs only under abnormal conditions, a fifth electrode known as a suppressor grid is placed between the screen grid and the plate. This suppressor grid (figure 8) is connected to the cathode or to ground potential. Thus a zero potential is established in the space between the screen grid and the plate. Under these conditions the screen grid has no effect on the electrons splashed out and all return to the plate so that no distortion can be introduced due to this cause. The electron tube containing the five electrodes is called a pentode. It will produce large power outputs with relatively small signal voltages applied to the grid.

Rectifiers

Recently the term mutator has been suggested to cover those forms of electronic devices which are designed for rectifying alternating current for power purposes. The term mutator thus includes grid-controlled hot-cathode rectifiers, mercury-arc rectifiers, and igniter-type mercury-arc rectifiers or ignitrons.

If the vacuum-type triode previously discussed be changed by the addition of gas under low pressure and if the grid be changed so that it completely surrounds the cathode, then a tube possessing some different and desirable properties is obtained. If this tube be connected in the circuit of figure 9, practically no current will flow from the cathode to the anode when the grid is free or not connected to any source of potential. This action is due to the fact that electrons emitted by the cathode land on the grid and make the grid negative. This negative grid repels nearly all electrons and does not permit many to pass through the meshes of the grid to the plate. If the grid is kept negative enough, the electrons cannot attain sufficient velocity to cause ionization and the tube is nonconducting between cathode and anode. As the grid is made less negative a point is reached where the electron velocity is great enough to cause ionization. Positive ions will then form a sheath around the grid and neutralize its effect and a large current flows to the anode. This current is limited only by the impedance of the anode circuit. Once started, the cathode-anode current cannot be stopped by any change of potential on the grid. If the grid circuit is opened, the positive ions will neutralize any electrons which land on the grid, and if the grid be made more negative, it will attract positive ions to its meshes and the resulting positive ion sheath will again neutralize the negative grid so that the cathode-anode current stream will be unaffected. The only way the anode current can be stopped when direct current is applied to the plate is to open the anode circuit.

The hot-cathode grid-controlled gaseous-conductor tube or thyratron finds its usefulness when an

alternating potential is applied to its anode circuit. Again, the tube can be started by placing a positive potential on the grid and the tube will function as a half-wave rectifier as long as the grid remains positive. If the positive potential be removed from the grid, the anode current will go to zero at the next negative wave of potential. Thus the starting and stopping of the rectification process can be controlled simply and perfectly (without arcing) by the application of a continuous potential to the grid. The grid may also be excited by a low alternating potential from the same source as the anode supply. If the grid and anode potential are in step, complete single-wave rectification will occur. If the grid potential be made to lag the anode potential, then rectification will start after the beginning of the cycle and the time and magnitude of the rectified current can be controlled. Thus a shift of phase of the grid voltage through 180 degrees will vary the rectified current from zero to a maximum of half-wave rectification. The thyratron gives fine control of rectified current and finds a wide application in theater stage lighting, flood lighting, motor speed control, and elsewhere.

Mercury-arc rectifiers have been used for rectification for many years. They operate upon the principle of a hot spot upon a mercury-pool cathode maintained by positive-ion bombardment. The arc is started by means of an auxiliary electrode. During recent years mercury-arc rectifiers have been built in large capacities for supplying direct current for electric railway operation. These rectifiers have been built in large steel tanks and use 3, 6, or 12 phases with a corresponding number of electrodes for anodes. For starting the main arc an auxiliary or exciting electrode must be in operation all of the time. The ionization produced by this auxiliary electrode produces conditions favorable for an arc-back or a reversal of the rectified current. Hence the anodes must be very carefully shielded and the arc path must be relatively long.

Quite recently a new method for starting the mercury arc in the rectifier has been invented by Slepian and Ludwig. The device using this new principle is called the ignitron. The ignitron is a mercury-arc rectifier having a third electrode or ignitor which consists of a rod of suitable refractory material which projects through the side of the tube and has a point dipping into the mercury pool. The ignitor electrode serves to fire the arc at will just as the grid of the thyratron may start the gaseous conduction. If the ignitor electrode be made positive with respect to the cathode pool and a suitable critical current be permitted for a few microseconds, a tiny spark occurs between the ignitor and mercury. If the anode potential is positive and of suitable value, this tiny spark expands into an arc which is transferred to the anode through the ionization process previously considered. The arc forms a very low resistance path for the passage of current.

The ignitor principle may be used for a single current surge of half-wave rectification or it may be used for several waves, or for continuous operation. The ignition process must be repeated each time the alternating anode potential becomes positive. The ignitor electrode may be fired from the same a-c source of potential as the anode. Also the phase relation of the ignitor voltage to anode voltage may be varied to give only partial or even zero time of rectification. Thus the ignitron has the same control characteristics as the thyratron. The ignitron is inherently suited for larger current values of rectified current than the thyratron. The advantages of the ignitron over the mercury-pool rectifier are long life of mercury-pool type of cathode, and low voltage drop in arc since cathode and anode may be very close together. The latter advantage results because no arc-back can occur on reverse cycle since firing occurs only at desired time (and not continuously due to auxiliary electrode). The applications of the ignitron include simple continuous rectification, rectification with control, motor speed control, welding, and circuit breaking with quicker response than mechanical devices.

Photoelectric Cells

It was suggested earlier that electrons may be ejected from some solids by the impingement of light rays. It appears that the high-frequency electromagnetic wave (visible or invisible) has the power of imparting energy to the electrons in the outer orbits of atoms of certain photosensitive materials so that these electrons are released or torn from the atom and fly out into space. This phenomenon forms the basis of action of the photoelectric cell or the "electric eye" which is so widely used in many control applications. The more common light sensitive materials are sodium, potassium, barium, strontium, and some of their compounds. The photoelectric cell usually consists of an evacuated tube containing a large area of light-sensitive material and a small anode or wire near the center. The cell is connected into a circuit so that a positive potential is applied to the anode. Whenever light falls on the light-sensitive cathode, electrons are emitted and attracted to the anode. The actual current flowing in the cathode-anode circuit is very small and amounts to only a few microamperes at the best. This small current produces a small voltage drop across a resistance. This potential is amplified by means of other electron tubes to produce a signal for performing the purpose desired. The number of electrons emitted from a light-sensitive surface is directly proportional to the intensity of light falling upon that surface. Thus a variation of light intensity may be transformed into an electric signal to perform a desired purpose. This principle is used in the sound production for the talking picture where a sound track on the film varies the light intensity falling on a photoelectric cell. The photoelectric cell may also be used for picture transmission, for television, and for all kinds of signal applications.

Photoelectric cells may have a high vacuum or may contain gas under low pressure. The emission of electrons by the impingement of light rays is the same in both types. The resulting current to the anode in the vacuum type is equal to the electron emission, but in the gaseous type the current is amplified several times (in practice not exceeding ten times) by the addition of current from the gas ions which are formed during the transit of electrons from the cathode to the anode.

News

Of Institute and Related Activities

Attractions at the AIEE 1938 Winter Convention

A PROGRAM comprised of many attractive features has been arranged for the AIEE 1938 winter convention, which will be held January 24–28 in New York City, with headquarters, as usual, in the Engineering Societies Building, 33 West 39th Street. To provide added interest for the membership the technical program has been enlarged to 16 technical sessions, 1 general session, and 5 conference sessions. This has been made possible without detracting in the least from the usual social functions: the smoker, Edison Medal presentation, dinner-dance, and inspection trips to places of interest. As in previous years, the women's entertainment committee, with Mrs. George Sutherland, chairman, is arranging a special program for the visiting women. For those who would enjoy a few days' vacation after the convention, and in view of the success of last year's cruise, another post-convention cruise to Bermuda has been arranged. A summarized schedule of events is given in an accompanying tabulation.

Edison Medal Presentation

Presentation of the AIEE 1937 Edison Medal to Gano Dunn will take place at a special session of the convention in the engineering auditorium, Wednesday, January 26, at 8:00 p.m. The medal was awarded to Mr. Dunn "for distinguished contributions in extending the science and art of electrical engineering, in the administration of great engineering works, and for inspiring leadership in the profession." A biographical sketch of the recipient is included in the "Personal Items" section of this issue.

General Session

Because of the great interest and importance of current economic problems to engineers, arrangements have been made for an address "Technological Development in Relation to Economics" by H. G. Moulton, president of the Brookings Institution, Washington, D. C. The address will be given at a "general session" scheduled for Wednesday morning, January 26. In order to give all members attending the convention an opportunity to hear Doctor Moulton's address no parallel sessions will be held that morning. It is believed that the women attending the convention will find the subject of interest, and they are cordially invited to attend. A somewhat similar session held during the summer convention at Milwaukee, Wis., last June illustrated the increasing importance of economic problems to the engineer. The program for this session is as follows:

Presiding: W. H. Harrison, president, AIEE

Opening Remarks: President Harrison

Convention Activities: T. F. Barton, chairman, winter convention committee

Presentation of Alfred Noble Prize to G. M. L. Sommerman

Address: Technological Development in Relation to Economics, H. G. Moulton, president, Brookings Institution

Table I. Issues of "Electrical Engineering" Containing 1938 Winter Convention Papers

July 1937	1 paper
September 1937	4 papers
October 1937	3 papers
November 1937	2 papers
December 1937	5 papers
January 1938	11 papers
Subsequent issues	*39 papers

* Advance copies of these papers will be made available at 10¢ each by mail, or 5¢ each if purchased at AIEE headquarters (see order form in advertising section of this issue).

Summarized Schedule of Principal Events

Monday, January 24	
9:00 a.m.	Registration
10:00 a.m.	Communication Symposium on modern electric vehicles–I
2:00 p.m.	Symposium on a new carrier telephone system for toll cable Symposium on modern electric vehicles–II Conference on radiation fields
Tuesday, January 25	
9:30 a.m.	Lightning protection Symposium on electronics–I Conference on education
2:00 p.m.	Relays and reactors Symposium on electronics–II Conference on sound and vibration
6:30 p.m.	Smoker at the Commodore Hotel
Wednesday, January 26	
10:00 a.m.	General session
2:00 p.m.	Instruments and measurements Electric welding Basic sciences
8:00 p.m.	Edison Medal presentation
Thursday, January 27	
9:30 a.m.	Power transmission Conference on network analysis and synthesis Electrical Machinery–I Conference on definitions
2:00 p.m.	Television Cables and research Electrical Machinery–II
7:00 p.m.	Dinner-dance at the Plaza Hotel
Friday, January 28	
All day	Inspection trips
Saturday, January 29	
3:00 p.m.	"Monarch of Bermuda" sails on post-convention cruise to Bermuda

Technical Program

In accordance with the new publication policy, advance copies of papers not published in Electrical Engineering prior to the convention (those listed without publication references, exclusive of addresses) will be available. The price of these advance copies when ordered by mail is 10¢ each; when purchased at headquarters, 5¢ each (see order form in the advertising section of this issue).

The 16 sessions of the tentative technical program announced in Electrical Engineering for December 1937, pages 1516–17, are complete except for subsequent changes made in the sessions on electric vehicles, electrical machinery, and television. The programs for these sessions, as revised, are repeated for convenience.

Symposium on Modern Electric Vehicles

The P.C.C. Street Car, C. F. Hirshfeld, Transit Research Corporation.

Application of Modern Electric Vehicles to Urban Transportation, C. M. Davis, General Electric Company.
January issue, pages 57–60 (Trans.)

Electrical Equipment for Modern Urban Surface Transit Vehicles, S. B. Cooper, Westinghouse Electric & Manufacturing Company.
January issue, pages 50–6 (Trans.)

Results of Operation of P.C.C. Cars in Pittsburgh, Thomas Fitzgerald, Pittsburgh Railways Company.

Modern City Transportation, E. J. McIlraith, Chicago Surface Lines.

Symposium on Modern Electric Vehicles—Continued

Modern Trolley-Coach Operation, Edward Dana, Boston Elevated Railway.
December issue, pages 1461–63

Modern Trolley-Coach Operation, **J. H. Polhemus,** Portland Electric Power Company.
December issue, pages 1483–86

Operating Experience With Gas-Electric and Diesel-Electric Buses, **R. H. Stier,** Philadelphia Rapid Transit Company.

Address: Electrically Propelled Rubber-Tired Highway Vehicles for Mass Transportation, **Martin Schreiber,** Public Service Co-ordinated Transport.

Electrical Machinery—I

Co-ordination of Power Transformers for Steep-Front Impulse Waves, **V. M. Montsinger,** General Electric Company.

Corona Voltages of Typical Transformer Insulations Under Oil, **F. J. Vogel,** Westinghouse Electric & Manufacturing Company.
January issue, pages 34–6 (Trans.)

A Formula for the Reactance of the Interleaved Component, **H. B. Dwight** and **L. S. Dzung,** Massachusetts Institute of Technology.
November issue, pages 1368–71

Electrical Machinery—II

Stray-Load Losses of D-C Machines, **E. W. Schilling,** Michigan College of Mining and Technology, and **R. W. Koopman,** University of Kansas.
December issue, pages 1487–91

D-C Machine Stray-Load-Loss Tests, **Victor Siegfried,** Worcester Polytechnic Institute.
October issue, pages 1285–89

Unsymmetrical Short-Circuits on Water-Wheel Generators Under Capacitive Loading, **C. F. Wagner,** Westinghouse Electric & Manufacturing Company.
November issue, pages 1385–95

Overvoltages Caused by Unbalanced Short Circuits—Effect of Amortisseur Windings, **Edith Clarke** and **C. Concordia,** General Electric Company, and **C. N. Weygandt,** University of Pennsylvania.

Alternator Short-Circuit Currents Under Unsymmetrical Terminal Conditions, **A. R. Miller** and **W. S. Weil, Jr.,** Lehigh University.
October issue, pages 1268–76

Television

Address: Current Field Work in Television, **Ralph R. Beal,** Radio Corporation of America.

Address: The Coaxial Cable System for Telephone Transmission, **M. E. Strieby,** Bell Telephone Laboratories, Inc.

Technical Conferences

The programs for the technical conferences in so far as they have been made available to date are given here. These conferences are intended to be informal in character. Preprints of the papers will not be available in advance of the convention, although a few prepared papers and prepared discussions may be used at the time of the convention for the purpose of stimulating pertinent discussion from the audience.

Radiation Fields. The following general papers on the physics of radiation are believed to provide a proper background for discussion. The object of the conference is by no means discussion of papers themselves, but fundamentally an exchange of newer ideas and research results on these topics.

Electromagnetic Radiation and the Impedance Concept, **S. A. Schelkunoff,** Bell Telephone Laboratories, Inc.

Sound Production and Collection (Emphasizing Electrical and Acoustical Analogies), **H. F. Olson,** Victor Division, Radio Corporation of America.

Elastic Waves in Solids and Surface Waves of Fluids, **H. Poritsky,** General Electric Company.

Sound and Vibration Measurement. This conference will constitute an open meeting on progress in the sound measurement field and related questions. The program tentatively arranged includes the following principal topics:

1. The proposed AIEE Test Code on Apparatus Noise Measurement will be reviewed, including consideration of changes that have been proposed since its publication, with a view toward rendering a final report to the standards committee recommending the publication of the code in pamphlet form.

2. Several speakers will present proposals for the development of noise measurement standards or specifications for particular lines of apparatus, following the general procedure of the AIEE test code. If the interest and the progress shown warrant it, the committee may undertake to organize a formal Institute session on the subject with published papers at the summer convention.

3. There will also be a general discussion of methods of measuring vibration, including the velocity and acceleration, as well as the amplitude of the motion. The desirability of the committee's sponsoring definitions and measurement methods in this field to supplement the work on sound measurement will be considered.

Informal Talks

Experiences With the Sound Level Meter Standards, **W. S. Barstow,** American Telephone and Telegraph Company.

Experiences With Noise Specification Tests, **A. P. Fugill,** The Detroit Edison Company.

Vibration Measurement Methods, **C. W. LaPierre,** General Electric Company.

Definitions. This conference of the subcommittee on definitions of the AIEE committee on basic sciences will consider the definitions in group 05 of the final revised report of the sectional committee on definitions of electrical terms (*C*-42). According to present arrangements for the conference each member of the subcommittee will present a set of suggested definitions and after each presentation discussion will be invited.

It is planned to invite to the conference all members of the following committees: basic sciences, sectional committee on electric and magnetic magnitudes and units (*C*-61), sectional committee on definitions of electrical terms (*C*-42), subcommittees of the sectional committee on electrical definitions, and other interested persons.

Smoker

The excellent facilities of the Hotel Commodore again have been made available for the smoker this year. The Grand Ballroom and West Ballroom with its lounge and service bar have been reserved. These facilities together with a good view of an excellent show and supper served by the experienced Commodore staff assure a pleasant evening. Don't miss this opportunity to chat with your friends amidst pleasant surroundings. The seating will be at tables of 10 with ample space to move around. Those planning to attend are urged to send their reservations to the AIEE Smoker Committee, 33 West 39th Street, New York, N. Y., at an early date. All tables will be reserved. Tickets will be $3.50 per person.

Dinner-Dance

The Grand Ballroom of the Hotel Plaza will be the setting for the outstanding social event of the convention, namely, the annual dinner-dance and buffet supper to be held Thursday evening, January 27. The Plaza, located on Fifth Avenue between 58th and 59th Streets and overlooking Central Park to the north, is known for its sparkling atmosphere and the excellence of its cuisine. Lounging rooms adjacent to the ballroom will be reserved for Institute members and their guests affording spacious and luxurious surroundings for meeting friends and acquaintances.

George Ellner and his orchestra again will provide music during the dinner and later for the dance. As in the past, encores will be limited in order to provide a maximum number of dances during the evening.

In order to start dancing earlier the dinner hour has been advanced as shown in the following schedule:

7:00 p.m.	Dinner
9:30 p.m. to 2:00 a.m.	Dancing
Midnight to 2:00 a.m.	Buffet supper

Tickets will be sold on the following plans:

Dinner and dance	$5.00 per person
Dinner, dance, and buffet supper	6.50 per person
Dance and buffet supper	3.00 per person

To assist the committee, an early pur-

Table II. A Few of the Hotels Available

Hotel	Location	Rooms With Private Bath: Single	Rooms With Private Bath: Double
Astor	Broadway and 44th Street	$3.50– 5.00	$6.00– 8.00
Biltmore	Madison Avenue and 43d Street	6.00–12.00	8.00–14.00
Bristol	129 West 48th Street	2.50– 4.00	3.50– 7.00
Commodore	Lexington Avenue and 42d Street	3.50– 5.00	5.00– 8.00
Edison	228 248 West 47th Street	2.50– 5.00	4.00– 8.00
Governor Clinton	31st Street and 7th Avenue	3.00– 5.00	4.00– 7.00
Lexington	Lexington Avenue and 48th Street	3.50– 5.00	4.50– 7.00
Lincoln	Eighth Avenue and 44th Street	3.00– 4.50	4.00– 6.50
McAlpin	Broadway and 34th Street	3.00– 7.00	4.50– 9.00
Montclair	Lexington Avenue and 49th Street	3.00– 5.00	5.00– 8.00
Murray Hill	Park Avenue and 40th Street	2.50– 4.00	4.00– 6.00
New Yorker	8th Avenue and 34th Street	4.00– 8.00	6.00–10.00
Pennsylvania	7th Avenue and 32d Street	3.50– 6.00	5.00– 9.00
Plaza	Fifth Avenue and 59th Street	7.00–10.00	9.00–14.00
Roosevelt	Madison Avenue and 45th Street	5.00– 9.00	7.00–12.00
Vanderbilt	Park Avenue and 34th Street	3.50– 5.00	6.00– 8.00
Waldorf-Astoria	Park Avenue and 50th Street	7.00–12.00	10.00–15.00

Future AIEE Meetings

Winter Convention
New York, N. Y., Jan. 24–28, 1938

North Eastern District Meeting
Lenox, Mass. (Pittsfield Section)
May 18–20, 1938

Summer Convention
Washington, D. C., June 20–24, 1938

Pacific Coast Convention
Portland, Ore., August 9–12, 1938

Southern District Meeting
Miami, Fla., November 1938

chase of tickets is requested. Dinner reservations should include names of guests and desired seating arrangements. Tables will be laid for 8 or 10 places and every effort will be made to satisfy the wishes of those attending. Reservation requests should be sent to the AIEE Dinner-Dance Committee, 33 West 39th Street, New York, N. Y., checks being made payable to "Special Account, AIEE."

Inspection Trips

During the week of the convention a number of interesting inspection trips will be arranged. Some of these will be related to the subjects of technical papers, and others will be of general interest.

The tentative list of inspection trips under consideration is as follows: photo-engraving plant, sponsored radiobroadcast, automobile assembly plant, vehicular tunnel, sewage treatment plant, stainless steel streamlined train, grid-controlled rectifier, high-pressure turbine unit, radio tube manufacturing, Stock Exchange, New York City Fire College, cable manufacturing plant, copper refining plant, Bell Telephone Laboratories, and television studios.

Through the courtesy of the General Electric Company, sponsor of the "Hour of Charm" radio program featuring Phil Spitalny and his all-girl orchestra, a limited number of tickets is expected to be available for the broadcast of that program on Monday evening, January 24. It is suggested that out-of-town members indicate their desire for tickets with their advance registration.

The Bermuda Cruise

Because of the success of last year's cruise, a second post-convention cruise to Bermuda has been arranged. At this popular resort, one may golf on fine courses, fish in waters that yield game fish and strange specimens, bicycle over limestone roads bordered by oleanders and hibiscus, visit the famous caves, ride on spirited horses or in gaily canopied victorias (there are no automobiles in Bermuda), or just sit on the terrace of the hotel and enjoy the beauty of the gardens and the distant landscape.

The cruise party will sail from New York January 29 at 3:00 p.m. and will return February 4 at 9:00 a.m. This will allow practically three days in Bermuda; for those who wish to stay longer, stop-over privileges are available. Rates for the trip depend on the location chosen on the ship, but begin at $85 per person, which includes every necessary expense—first-class round-trip transportation, rooms with bath and all meals both on ship and in Bermuda at the Hotel Bermudiana, all government taxes, and a visit to old St. Georges. It does not include tips or sightseeing expenses, both of which should cost less than $15 total. Those making the earliest reservations will have the greatest opportunity to choose accommodations at the lower rates. Full information may be obtained from Leon V. Arnold, cruise director, 36 Washington Square West, New York, N. Y.

Hotel Rates and Registration

Reservations for hotel accommodations should be made by writing directly to the hotel of your preference. In table II is included a brief list of some of the leading hotels in the vicinity.

Members in near-by Districts should fill in and post promptly the mail registration card included with the mailed announcement of the winter convention. This will permit the committee to have badges ready and prevent congestion at the registration desk upon arrival. There will be a registration fee of $2 for non-members with the exception of Enrolled Students of the Institute, and the immediate families of members.

A typical scene in Bermuda

Winter Convention Committee

The personnel of the 1938 winter convention committee is as follows: T. F. Barton, *chairman*, C. R. Beardsley, O. B. Blackwell, G. E. Dean, A. F. Dixon, E. E. Dorting, H. S. Osborne, C. S. Purnell, George Sutherland, and F. P. West. The chairmen of the subcommittees completing the arrangements are: C. M. Gilt, *dinner-dance;* E. S. Banghart, *smoker;* E. R. Thomas, *inspection trips;* and Mrs. George Sutherland, *women's entertainment.*

Alumni Gatherings

During winter-convention week, the following special gatherings will be held by college alumni organizations.

Columbia Electrical Engineering Alumni, January 24, 6:30 p.m. An informal dinner at $1.50 per plate will be held at the Columbia University Club, 4 West 43d Street. Reservations may be sent to J. W. Balet, 4 Irving Place, New York, N. Y.

Brown Engineering Association, January 26, 12:30 p.m. Informal luncheon will be held at the Hotel Bristol, 129 West 48th Street. Reservations may be sent to A. E. Cuddeback, 36–22 208th Street, Bayside, N. Y.

District 6 Award for Branch Paper

A prize for Branch paper for the academic year ending June 30, 1937, has been awarded by the AIEE North Central District (No. 6) to John K. McKendry (Enrolled Student) for his paper "The Development of Sound Pictures," which was presented at the tenth annual conference of Student Branches in the District held at South Dakota State College, Brookings, April 23–24, 1937. The award was made in accordance with the revised rules governing prizes for AIEE papers recently adopted by the Institute's board of directors (*EE, April '37, p. 492*), which stipulate that prizes for Branch papers shall be awarded on the basis of the academic year, July 1 to June 30, inclusive.

Bonneville Advisers Appointed. The four-man advisory committee that will co-operate with J. D. Ross (A'08, F'12) newly appointed administrator of the Bonneville power development on the Columbia River, has been completed by the action of the various federal departments concerned. The members of the committee will act as liaison officers to keep the administrator in touch with plans of their respective agencies which may affect or be affected by the Bonneville development. The members and the departments they represent are: Frank A. Banks, Department of Interior; Halbert Selby, Department of Agriculture; Thomas M. Robins, War Department; and Roger B. McWhorter, Federal Power Commission.

Committee Appointed for Pacific Coast Convention

Appointment of the 1938 Pacific Coast convention committee by President W. H. Harrison and the approval of the convention dates as August 9 to 12 have set in motion much activity by members of Portland (Ore.) Section in an effort to make the convention, which is to be held in that city, the most successful on record. According to C. B. Carpenter, publicity subcommittee chairman, all subcommittees already are functioning. The date of the convention has been set ahead of the customary date in order that members from other sections of the country more conveniently may combine attendance at the convention with a vacation trip to the Pacific Coast.

E. F. Pearson has been named general chairman of the convention committee; to assist him the following have been appointed: D. F. Smith, *vice-chairman;* Corbett McLean, *secretary;* John Bankus, *treasurer;* Walter Brenton, *meetings and papers;* O. B. Coldwell, *finance;* S. E. Caldwell, *registration;* R. J. Davidson, *hotel arrangements;* V. B. Wilfley, *inspection trips;* C. B. Carpenter, *publicity;* L. R. Elder, *reception;* A. H. Kreul, *entertainment;* J. C. Henkle, *golf;* A. L. Albert, *student activities;* G. E. Bishop, *transportation;* and Mrs. J. F. Spease, *women's entertainment.*

H. G. Moulton to Address Convention General Session

As announced elsewhere in this issue, H. G. Moulton, president, The Brookings Institution, Washington, D. C., will be the principal speaker at the "general" session of the Institute's 1938 winter convention to be held Wednesday morning, January 26. Doctor Moulton's subject will be "Technological Development in Relation to Economics," and his address will follow immediately after the presentation of the Alfred Noble prize to G. M. L. Sommerman (A'31, M'37), which will take place after the opening remarks of President W. H. Harrison and T. F. Barton, general chairman of the winter convention committee.

Doctor Moulton has been a student of political economy for many years. Following his graduation from the University of Chicago in 1907 with the degree of bachelor of philosophy, he engaged in a teaching career, becoming a fellow in political economy at the University of Chicago in 1909, and advancing to full professorship at that institution in 1922. He was granted a degree of doctor of philosophy from the University of Chicago in 1914. In 1922 he became director of the Institute of Economics at Washington, D. C. This body was amalgamated with the Institute for Government Research and the Robert Brookings Graduate School of Economics and Government in 1928 to form the Brookings Institution, and Doctor Moulton has been president of that organization since that time.

Doctor Moulton is a fellow of the American Association for the Advancement of Science (vice-president, 1936) and a member of the American Academy of Arts and Sciences. He is author of a number of books on political and economic issues, and has delivered many lectures on those subjects. In April 1937 he gave the Eleventh Steinmetz Memorial Lecture entitled "Engineering Progress and Economic Progress"

H. G. Moulton

before the AIEE Schenectady Section (*EE, May '37, p. 510–17*). He has received the honorary degree of doctor of laws from several institutions.

This "general" session is the second of its type to be sponsored by the AIEE, the first having been held during the Institute's 1937 summer convention at Milwaukee, Wis. Arrangements for the session were made by a special committee appointed by Chairman H. S. Osborne of the technical program committee and consists of H. S. Bennion, C. R. Beardsley, L. W. W. Morrow, Mr. Osborne, and W. E. Wickenden.

Executive Committee Meets at Institute Headquarters

A meeting of the executive committee of the American Institute of Electrical Engineers was held at Institute headquarters, New York, N. Y., December 15, 1937, in place of the regular meeting of the board of directors.

Present: W. H. Harrison, *chairman,* O. B. Blackwell, F. M. Farmer, A. M. MacCutcheon, W. I. Slichter, members of the committee; C. R. Beardsley, member of the board of directors; National Secretary H. H. Henline.

Recommendations adopted by the board of examiners at a meeting held November 18, 1937, were reported and approved. Upon recommendation of the board of examiners, the following actions were taken: 2 applicants were transferred to the grade of Fellow; 1 applicant was elected to the grade of Fellow; 29 applicants were transferred, 15 were elected, and 1 was reinstated to the grade of Member; 130 applicants were elected to the grade of Associate; 853 Students were enrolled.

Approval was given to monthly disbursements, reported by the finance committee, amounting to $19,571.43 in November and $19,695.09 in December.

Announcement was made of the award by the Edison Medal Committee, on December 10, of the 1937 Edison Medal to Gano Dunn.

Appointments of Institute representatives, recommended by the standards committee, were reported and confirmed, as follows. Frank B. Powers as chairman of the sectional committee on railway motors —*C*35, and L. C. Ilsley as Institute representative on the mining standardization correlating committee; and confirmation was given to the approval by the standards committee of the naming of William Seubert as chairman of the sectional committee on industrial control—*C*19, of which the National Electrical Manufacturers Association and AIEE are joint sponsors.

W. C. Wagner was appointed AIEE representative on the committee on low voltage hazards of the American Society of Safety Engineers, the engineering section of the National Safety Council, for the administrative year ending July 31, 1938.

Upon recommendation of the executive committee of the Pittsburgh Section, Vice-President I. Melville Stein of the Middle Eastern District, and the chairmen of the finance and Sections committees, authority was granted for the addition of Centre, Clearfield, and Jefferson Counties, Pennsylvania, to the territory of the Pittsburgh Section.

An invitation from The Institution of Engineers, Australia, to the AIEE to appoint an official representative to attend the annual engineering conference of The Institution, at Sydney, N.S.W., during the week of March 28, 1938, in connection with Australia's 150th anniversary celebration, was referred to the national secretary with power.

It was decided that the January 1938 meeting of the board of directors would be held Wednesday afternoon, January 26, during the winter-convention week.

Other matters were discussed, reference to which may be found in this or future issues of ELECTRICAL ENGINEERING.

World Radio Convention. The Institution of Radio Engineers (Australia) is organizing a world radio convention to be held at Sydney, April 4–14, 1938. This is believed to be the first world radio convention ever held anywhere to discuss all phases of radio engineering, embracing all persons interested in radio; technical subjects include wave propagation, telecommunication, broadcast transmission and receivers, sound projection, electromedical, and television. Prominent engineers from all parts of the world are expected to attend. The convention is being held during the celebration of the 150th anniversary of the foundation of Australia. All interested persons are invited to communicate with the convention secretary, O. S. Mingay, 30 Carrington Street, Sydney.

AWS Officers for 1938. Election of the following new officers of the American Welding Society for 1938 was announced at the recent annual meeting of the society: *President*—P. G. Lang, Jr., engineer of bridges, Baltimore and Ohio Railroad, Baltimore, Md.; *Senior Vice-President*—

Membership—

Mr. Institute Member:

The returns from this year's "round robin," in which we asked for your co-operation in obtaining additional members, have been coming in steadily. The recommendations contained in them are extremely helpful to us and you are urged to send yours along, if you have not already done so.

We would like you to think of possible prospects within your knowledge who are eligible, though not at present members, and who might be interested in joining the Institute. Send their names and addresses to your Membership Committeeman now while the busy season is in the making.

If you will perform this service at the expense of a small amount of your time, your local membership officer will do the rest. Together we can render a valuable service, both to the Institute and to the new members whom we enroll.

Thank you.

Eliot McCormick

Vice-Chairman, District No. 3
National Membership Committee

G. F. Jenks, chief of technical staff, Office of Chief of Ordnance, United States Army, Washington, D. C.; *Divisional Vice-Presidents*—K. V. King, Standard Oil Company of California, San Francisco, and W. J. Sanneman, Tennessee Coal, Iron & Railroad Company, Birmingham, Ala.; *Directors at large*—A. M. Candy (A'15, M'20) Hollup Corporation, Chicago, Ill.; J. H. Deppeler, Metal & Thermit Corporation, New York, N. Y.; E. R. Fish, The Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.; A. E. Gaynor, J. A. Roebling's Sons Co., New York, N. Y.; L. S. Moisseiff, consulting engineer, New York, N. Y.

Cash Prizes for Papers Partially Restored

Provision in the Institute's 1937–38 budget has been made for cash awards to accompany the national and District prizes for initial and Branch papers to be awarded during the current year. In recent years, no prizes have been accompanied by cash awards except the District prizes for Branch papers.

All technical papers presented before the Institute during the year are eligible under the AIEE paper prize regulations for competitive consideration for one or more of the established prizes, regardless of whether presented before a Branch meeting, a Section meeting, a District meeting, or a national convention, the several classes providing for equitable competition. With the exception of the prizes for Branch papers, both District and national prizes are awarded each spring for papers presented during the preceding calendar year. For Branch papers, both national and District prizes are awarded on the basis of the academic year, July 1 to June 30, inclusive. Suitable certificates accompany all awards.

National prizes that may be awarded annually, and those to be accompanied by cash awards during the current year, are as follows:

1. Best paper prizes:
   - *Engineering practice*
   - *Theory and research*
   - *Public relations and education*
2. Prize for initial paper ($100)
3. Prize for Branch paper ($100)

District prizes that may be awarded annually, together with the cash awards provided for the current year, are:

1. Prize for best paper
2. Prize for initial paper ($25)
3. Prize for Branch paper ($25)
4. Prize for graduate student paper

Although all papers presented are *eligible*, there is no provision for automatic consideration of papers, except that those approved by the technical program committee and presented at national conventions or District meetings will be considered by the national prize committee for the national "best paper" and the "initial paper" prizes without being offered formally for competition. All other papers for which prize consideration is desired must be *submitted* specifically for that purpose, through the District secretary for District prizes, or through the national secretary's office for the national prizes.

Deadline Dates

Papers to be considered for 1937 national prizes must be submitted not later than February 15, 1938. Papers to be considered for the District "best" and "initial" paper prizes must be submitted on or before February 15, 1938; for the District, Branch and graduate student paper prizes, before July 15, 1938 (for papers presented during the academic year ending June 30, 1938). Those wishing further information may obtain a booklet entitled "National and District Prizes" by writing to AIEE Headquarters, 33 West 39th Street, New York, N. Y.

Broadcast Engineering Conference. The department of electrical engineering of The Ohio State University, Columbus, is sponsoring a conference or short course on broadcast engineering during the period February 7–18, 1938. The purpose is to bring together leaders in the industry and practicing engineers from all parts of the United States and Canada in a discussion of some of the most important technical problems. Sessions will consist of a formal lecture by the leader, followed by round-table discussion. Registration will be limited. Speakers at the various sessions and their subjects are as follows:

H. H. Beverage (A'23, M'34) chief research engineer, R.C.A. Communications, Inc.—ultrahigh frequency propagation.

G. H. Brown, member of firm, Godley and Brown, consulting engineers—broadcast antenna design. J. F. Byrne (A'32) engineer, Collins Radio Company—field strength surveys.

J. H. Dellinger, chief of radio section, National Bureau of Standards—propagation of broadcast frequencies at night.

W. H. Doherty, radio development department, Bell Telephone Laboratories, Inc.—high-power radio-frequency amplifiers.

W. L. Everitt (A'25, F'36) professor of electrical engineering, The Ohio State University—coupling networks.

H. M. Hucke, chief communications engineer, United Airlines Transport Corporation—snow static effects on aircraft.

G. M. Nixon (A'28) development engineer, National Broadcasting Company—studio acoustics.

Harold L. Olesen (M'27) assistant general sales manager, Weston Electrical Instrument Corporation—indicating instruments.

P. C. Sandretto, communications engineer, United Airlines Transport Corporation—some principles in aeronautical ground radio station design.

A. E. Thiessen, commercial engineering manager, General Radio Company—modulation and distortion measurements.

Perkin Medal Awarded. The Perkin Medal of the Society of Chemical Industry has been awarded to F. J. Tone, president of The Carborundum Company, Niagara Falls, N. Y., and will be presented to him at a joint meeting of the American section of that society and the American Chemical Society, January 7, 1938. The medal is awarded annually for the most valuable work in applied chemistry, and is given to Doctor Tone for his work in the field of abrasives and refractories.

AIEE Officers to Be Nominated Soon

In accordance with the Institute's by-laws, the national nominating committee of the AIEE will meet during the winter convention to be held in New York, N. Y., January 24–28, 1938, for the purpose of nominating national officers to be voted upon by the membership in the spring of 1938. Members of this year's national nominating committee are as follows:

Representing the Board of Directors

C. R. Beardsley, Brooklyn Edison Company, Brooklyn, N. Y.

O. B. Blackwell, Bell Telephone Laboratories, Inc., New York, N. Y.

Vannevar Bush, Massachusetts Institute of Technology, Cambridge

R. W. Sorensen, California Institute of Technology, Pasadena

A. C. Stevens, General Electric Company, Schenectady, N. Y.

C. R. Jones, *alternate*, Westinghouse Electric & Manufacturing Co., New York, N. Y.

Representing the Ten Geographical Districts

1—W. H. Timbie, Massachusetts Institute of Technology, Cambridge

2—J. H. Lampe, Johns Hopkins University, Baltimore, Md.

3—R. H. Tapscott, Consolidated Edison Company of New York, Inc., New York, N. Y.

4—Mark Eldredge, Memphis Power and Light Company, Memphis, Tenn.

5—W. T. Ryan, University of Minnesota, Minneapolis

6—L. N. McClellan, United States Bureau of Reclamation, Denver, Colo.

7—A. L. Maillard, Kansas City Power and Light Company, Kansas City, Mo.

8—F. B. Doolittle, Southern California Edison Company, Ltd., Los Angeles

9—E. F. Pearson, Northwestern Electric Company, Portland, Ore.

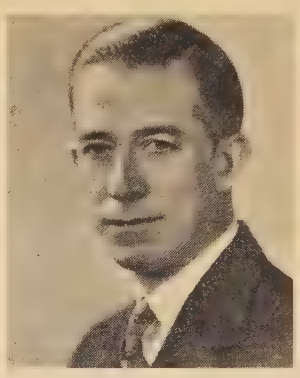
10—M. J. McHenry, Canadian General Electric Company, Ltd., Toronto, Ontario

Provisions of the AIEE constitution and by-laws relating to nominations were given in Electrical Engineering for November 1937, page 1415. In addition to those to be designated by the national nominating committee, nominations also may be made independently. Briefly, independent nominations may be made by a petition of 25 or more members sent to the national secretary at Institute headquarters, not later than March 25, to be placed before the nominating committee for inclusion in the ballot of such candidates as are eligible. Petitions for the nomination of vice-president may be signed only by members within the District concerned.

Course in Building Illumination. Beginning early in February 1938, an evening course in illumination of buildings will be given at Columbia University, New York, N. Y., under joint sponsorship of the school of architecture and the department of electrical engineering. Although specially intended for architects and designers, the course contains much of value and interest to those connected in other ways with lighting. The course will be conducted by A. L. Powell (A'13, F'26) supervising engineer, Atlantic division, incandescent lamp department, General Electric Company, New York, N. Y., and past chairman of the AIEE committee on production and application of light. Other lecturers will include: Lillian E. Eddy, L. J. Buttolph (M'36), R. E. Clisdell, T. C. Lindholm, R. G. Morison, and K. Staley.

Business Manager for "EE" Appointed

At the suggestion of the AIEE publication committee, F. A. Norris, office manager at Institute headquarters, has been appointed business manager of Electrical Engineering. In this capacity, Mr. Norris will be responsible for all business matters pertaining to the Institute's publications. In his capacity as office manager, he has handled many of these matters for some years, so that his new appointment represents primarily a recognition of his services to the Institute's publications.



F. A. Norris

Mr. Norris has been associated with the AIEE headquarters staff since 1904, when he entered the business world. Appointed officer manager in 1913, he has been intimately associated with practically every phase of Institute activities during the past 25 years. A large part of the voluminous correspondence with members, with the officers of Institute Sections and Branches, and with Institute committees generally has been handled across his desk. Other important duties include the supervision of Institute accounts, the maintenance of all membership records, and the issuance of the AIEE Year Book. Of especial importance has been his long responsibility for the preparation and administration of the Institute's annual budgets.

Eta Kappa Nu Announces 1937 Awards

Chauncey Guy Suits of the research laboratory of the General Electric Company, Schenectady, N. Y., has been selected by Eta Kappa Nu, honorary electrical engineering society, as the outstanding young American electrical engineer for 1937. Doctor Suits was chosen from 60 candidates nominated from every section of the country, and becomes the second man to receive this honor. [In 1936, Frank M. Starr (A'30, M'37) also of the General Electric Company, received the first award to be made.] Three honorable-mention awards for 1937 also have been made to: Leonard L. Carter (A'29, M'35) assistant chief engineer of the Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.; Philo T. Farnsworth, president of Farnsworth Television, Inc., Philadelphia, Pa.; and Clifford A. Faust (A'35) of the advertising department of the Ohio Brass Company, Mansfield.

The awards were made by a committee of seven prominent engineers, five of whom were not members of Eta Kappa Nu: Vannevar Bush (A'15, F'24, director), Massachusetts Institute of Technology, Cambridge; H. P. Hammond, Pennsylvania State College, State College; A. M. Dudley (A'08, F'13), marine electrical engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.; T. F. Barton (A'12, F'30), district engineer, General Electric Company, New York, N. Y.; and H. H. Beverage (A'23, M'34) of the Radio Corporation of America, Riverhead, N. Y. The other two members were John W. Weigt (A'19, M'26), Electric Storage Battery Company, New York, N. Y., and Merle C. Hale, General Motors Corporation, New York, N. Y., both past national officers of Eta Kappa Nu.

The Eta Kappa Nu Award for young engineers who have been graduated not more than ten years and who are not yet 35 years of age was inaugurated two years ago to assure their recognition for "meritorious service in the interests of their fellowmen," and provide examples for newly graduating electrical engineers of what they might expect to attain within ten years through an alert and industrious development of their opportunities. Since an engineering education is presumed to prepare a man for a wide variety of achievements, an attempt is made by the committee of judges to appraise all of a man's activities—technical, civic, social, and cultural—in making the final selections.

Nominations of candidates for the 1937 awards were received from heads of electrical-engineering departments of American colleges, from sections of the AIEE, and individual members and chapters of Eta Kappa Nu. Doctor Suits' name will be engraved on the large bronze bowl permanently displayed at AIEE headquarters in the Engineering Societies Building in New York City. He will be presented with a small bronze replica of this bowl at the citation dinner to be held in New York during the week of the AIEE winter convention, January 24–28, 1938, and the honorable mention recipients will receive appropriate certificates on the same occasion.

ASTM Standards on Insulating Materials. The 1937 compilation of "ASTM Standards on Electrical Insulating Materials" has been issued by the American Society for Testing Materials. In addition to the current report of ASTM committee *D*-9 on electrical insulating materials, this 373-

page publication includes all of the 37 ASTM specifications and test methods covering the various types of insulating materials. In addition, there are two proposed standards covering tests for neutralization number of petroleum products and specifications for rubber insulating blankets. Of particular interest in the edition are the three discussions on significance of tests involving dielectric strength tests, resistivity tests, and impact tests, prepared by three prominent technologists. Copies can be obtained from ASTM Headquarters, 260 South Broad Street, Philadelphia, Pa., at two dollars each in heavy paper cover, with special prices on orders for ten or more copies.

Commercial Laboratories Form an Association

Representatives of 20 of the principal commercial laboratories of the United States, at a recent meeting in Chicago, Ill., completed the organization of the American Council of Commercial Laboratories. One of the purposes of the council will be the promotion of the proper use of scientific testing methods for the protection and certification of quality in advertised goods.

In behalf of the council it is stated that the members have been and will be carefully selected to include only organizations to which producers, retailers, and consumers may look for unbiased determinations of quality. Engaging in research and testing for fees, these independent laboratories ascertain and report facts for clients and are uninfluenced by any ulterior consideration. Laboratories which are adjuncts of other enterprises, or which are not self-supporting, or which for any reason are not independent, are ineligible for membership in this council.

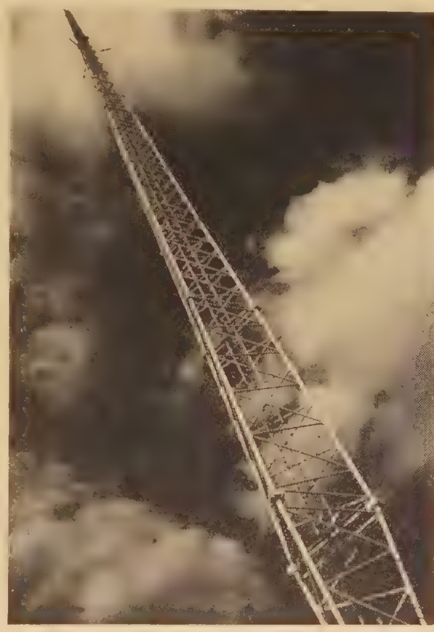
The following officers and members of an executive committee were elected to serve during 1938: P. S. Millar (A'03, M'13) Electrical Testing Laboratories, New York, N. Y., *president;* M. L. Patzig, Patzig Testing Laboratories, Des Moines, Iowa, *vice-president;* D. E. Douty, United States Testing Company, Hoboken, N. J., *secretary;* and A. R. Ellis, Pittsburgh Testing Laboratory, Pittsburgh, Pa., *treasurer;* J. H. Herron (M'35) The James H. Herron Company, Cleveland, Ohio; F. B. Porter, Southwestern Laboratories, Fort Worth, Texas; and T. A. Wright, Lucius Pitkin Inc., New York, N. Y., executive committee.

Wear of Metals. A "Symposium on Wear of Metals" has been published by the American Society for Testing Materials, and is comprised of six technical papers and related discussions that were presented at a recent meeting of the society. Subjects include considerations involved in the wear testing of metals, wear testing of cast iron, wear of metals from the automotive, power equipment, and railroad viewpoints; and wear of metals in the textile industry. Copies can be obtained from ASTM headquarters, 260 South Broad Street, Philadelphia, Pa., at $1.25 each.

New Antenna for KDKA Extends Service Area

The primary service area of KDKA, pioneer radiobroadcasting station, is said to have been increased tenfold by a 710-foot radiator recently erected at Saxonburg, near Pittsburgh, Pa. The 60-ton mast is composed of 32 three-cornered welded steel sections, five feet wide, bolted together and held upright by insulated guy wires attached at the 270-foot and 526-foot levels. The bottom section rests on a porcelain insulator, and other insulators are inserted to break the antenna, electr cally, at the 336-foot level.

A circle of eight 90-foot antennas which are designed to suppress, by out-of-phase radiation, high-angle radiation from the main antenna which they surround, extends the fading zone to greater distances from



the station. The high-angle radiation, or sky wave, causes fading by interference with the ground wave upon which the primary service area depends. The radiator operates at three-quarters wave length, but by the method of feeding radio frequency power to the tower, the current is maintained in phase throughout the entire length.

Cincinnati Section Organizes Study Group

A study discussion group has been established by the AIEE Cincinnati Section with the considered objective, as developed and adopted at its first meeting, of: "The adjustment of the engineer to present-day social conditions, to the end that he may be of the greatest service to the community, state, and nation." The group meets once a month, and its meetings are open to all members of the Section.

At the initial meetings, articles on social and economic subjects that have appeared in recent issues of ELECTRICAL ENGINEERING have constituted the principal subjects discussed. No fees of any kind are required, but members intending to join are expected to study the discussion material and be prepared to take part in the discussion. The steering committee consists of J. A. Noertker, C. D. Coy, E. F. Nuezel, V. G. Rettig, and C. F. Lee.

Standards Association Holds Annual Meeting

Completing its 19th year of service as national standardizing agency, the American Standards Association at its annual meeting held recently in New York, N. Y., reported the largest increase in membership of any year since the association was formed. A total of 16 national groups have become affiliated during the past year, including several in the building field, two in the automotive industry, and the National Retail Dry Goods Association with 5,800 store members, which is the first retailing group to become affiliated.

During the year, 59 standards have been approved, which increases to 382 the number of American standards adopted since the association was organized in 1918 to act as a clearing house for the many standardization activities of trade associations, technical societies, and government bureaus in the United States. Among the more significant electrical standards approved during 1937 were revisions of the National Electrical Code and of the Elevator Safety Code incorporating many new provisions for safe practices in elevator design and operation made as the result of research carried on at the National Bureau of Standards for the elevator industry.

In connection with its international work, the association has been invited to fill a vacancy on the council of the International Standards Association; P. G. Agnew, ASA secretary, was appointed the official ASA representative. Through the association, business interests in this country are participating in several international standardization projects. The adoption last year of the standard developed by the American Society of Motion Picture Engineers as world standard, the international standardization of bearings, the inch-millimeter conversion tables, already have pointed the way to what can be accomplished through co-operation with the other industrial countries of the world.

Following a luncheon, Frank B. Jewett (A'03, F'12, past-president), vice-president, Bell Telephone Laboratories, spoke on "Thirty Years of Standardization in Retrospect." Officers elected for 1938 are:

President—D. D. Barnum (re-elected). Mr. Barnum is a past-president of the American Gas Association and has served on the Board of ASA since 1933.

Vice-President—E. A. Prentis, vice-president, Spencer, White and Prentis, New York, N. Y. (re-elected).

Chairman, Standards Council—F. M. Farmer (A'02, F'13, director) vice-president, Electrical Testing Laboratories, New York, N. Y. (re-elected).

Vice-Chairman, Standards Council—R. P. Anderson, secretary, division of refining, American Petroleum Institute, New York, N. Y.

Business Paper Publisher Dead. Nelson W. Gage, chairman of the board of The Gage Publishing Company, New York, N. Y., died October 5, 1937, at the family homestead, Delanson, N. Y., after an illness of short duration. A native of Knox, Albany County, N. Y., where he was born in 1864, Mr. Gage, after attending Union College, came to New York as a young man where he was first employed in various capacities in the then struggling business publication field. In 1892 he founded his own company of which he was president until 1931 when he retired from active participation in its management. The Gage Company at one time published *Electrical Record* and at present publishes *Electrical Manufacturing*.

Current Items From American Engineering Council

Federal, State, and Local Planning

Operational planning of public enterprise is becoming universal in the United States according to the annual report of the National Resources Committee released November 10, 1937, and it is indicated that serious efforts now are being made to determine the "strategies of civilizations" and to provide national social and economic policies for present and future generations. However, many engineers most experienced in planning operations question the value of national planning which involves the determination of a pattern of living for future generations.

In reviewing its efforts to stimulate planning and to encourage decentralization of planning activities, the National Resources Committee has pointed out that, in addition to the 46 state planning boards, there are now approximately 400 county planning agencies and more than 1,700 similar groups in towns and cities. The committee predicts that state planning boards will increase their resources and usefulness through closer co-operation with other planning bodies, and expand their activities as state legislatures increase planning appropriations. Of the 1,700 municipal planning or zoning agencies, some 1,200 have continuous planning boards for making adjustments in zoning ordinances and for initiating plans for physical improvements including public buildings, parks, thoroughfares and the better use of available resources.

Secretary Ickes, in his letter to President Roosevelt transmitting this Report, states that "continuous planning is needed for the conservation and wise development of our national resources—both natural and human. With new inventions, new ideals, and new discoveries, no fixed plan or policy will suffice, for any rigid mold or blueprint plan, if strictly adhered to, may restrict our freedom rather than enlarge it. If we adopt as our constant objective to hand down to our children an unimpaired physical inheritance in the natural wealth of this continent, then we must make new plans to meet new conditions."

Many engineers are likely to welcome the philosophy that "no fixed plan or policy will suffice," and most of us will agree that any effort to mold our future may "restrict our freedom rather than enlarge it." Member societies should congratulate Secretary Ickes and encourage him to have that principle firmly established as the guiding influence for the National Resources Committee and all its subcommittees. In that way, engineers and engineering organizations may be constructive in their efforts to prevent the enforcement of misguided attempts to predetermine an exact plan of social and economic life for unborn generations to our citizens.

On the subject of regional planning, the National Resources Committee says that "there have always been interstate problems, and we have always had to use some kind of negotiation or planning to meet the critical situations as they arise. It is, therefore, nothing new to have interstate compact commissions and planning agencies studying alternative methods of solution for pressing problems which involve more than one state." The Report then proceeds to name a number of regional planning activities and "demonstration projects" in the Central Northwest, New England, the Ohio Valley, and the Pacific Northwest where it is said that real progress is being made on such problems as flood control, reclamation work, and power policy. A limited number of copies of the report are available from the National Resources Committee, Interior Building, Washington, D. C.

Congress—Special and Regular Sessions

Engineers and engineering societies seem to be particularly interested in the special and regular sessions of this Congress, and for that reason they may wish to know what Washington expects to see Congress do about some of its major issues. No one dares say what will be done, because obviously there are certain to be numerous changes in attitude; but all observers agree that, even at the beginning of a minor campaign year, there are unusually encouraging indications of more independence in thought and action.

The special session is referred to by some as "a brush cutting" session, in which may be seen a number of strategic maneuvers by the Administration to free legislation which is now tightly locked in committees, while the more courageous independent thinkers are fortifying themselves against pressures which heretofore have forced them to vote against their better judgment and wishes.

The Black-Connery Wage-Hours Bill, locked up in the rules committee of the House, is faced with an increasing demand for sweeping revisions even though it passed the Senate last session. Opposition seems even stronger now from all parts of the United States. Representative Lamneck of Ohio has enlisted both southern and western support for a substitute measure which would put the Federal Trade Commission in control and give the states greater control over maximum hours and minimum wages. Secretary of Labor Perkins is also reported to be actively preparing to propose changes as soon as the present bill is out of the rules committee. Organized labor is expected to demand that the powers of the proposed labor Standards Board be reduced before enactment of such far-reaching legislation.

Senator Byrnes of South Carolina is scheduled to lead a real fight for an omnibus reorganization bill, but powerful opposition by Senator Byrd of Virginia makes early passage questionable. Members of the House already have four bills for government reorganization, and it is common knowledge that many influential members of both Houses oppose giving any president all the power proposed by Senator Byrnes. The Division of opinion and the unwillingness of Congress to "clip the wings of the comptroller general" or otherwise surrender control of administrative functions to the White House are estimated to be strong enough to delay action and possibly defeat the major portion of the reorganization program.

The TVA regional planning ideas, although covered by separate legislation, are being discussed in connection with government reorganization. At the last session, the Senate agricultural committee and the House rivers and harbors committee held incomplete hearings on Norris S. 2555, Mansfield H. R.7365 and Rankin H.R. 7863. Every one of these bills is labeled conservation, but in reality they involve public power development and carry far-reaching social implications. At the close of last session, committee leaders indicated that further hearings would be unnecessary, but heightened interest by opposition within Congress to the legislation is said to be responsible for the announcement that hearings on the Mansfield Bill, at least, will be resumed. In a few words, the "Little TVA's" face anything but unanimity of approach to the problem of regional planning for conservation.

Under the guidance of Chairman Byrnes of South Carolina, a special senate committee is to investigate the unemployment and relief situation. Several executives from the Works Progress Administration are handling the work for the committee. It is expected that there will be extended hearings during which engineers and other professional and business groups will be invited to express themselves regarding permanent relief from our unemployment difficulties. In the meantime, Harry L. Hopkins and his associates are preparing for an increase in unemployment and relief expenditures. They are proceeding cautiously because Congress is reported to be less impulsive about reopening the relief coffers, even to

satisfy the less responsible elements of their respective constituencies.

A sudden awakening to the fact that we are not out of "the depression is disturbing Congress as well as the President and his Administration. Curtailed production and increasing unemployment coming parallel with the cessation of "pump-priming" activities are presenting problems ladened with serious implications. The stock market crash is the more visible of the major difficulties, but fundamental economic disturbances must be dealt with more effectively by Congress, the Administration and courageous citizens in both public and private life, without too much watchful waiting and hopeful wishing, to avoid a repetition of the disastrous experiences of the early thirties.

Congress responded to the call for the special session with a new appetite for factual information which evidences serious intention to act with more deliberation with reference to new legislation and large appropriations. Such a disposition is reflected in the number and importance of requests received by AEC for expressions of considered engineering opinion and engineers' interpretation of the implications of proposed legislation.

All questions of major importance are referred to Council's committees whenever there is sufficient time for such action. On short notice, the staff responds with the accumulated expressions of opinion from member societies and their representatives. Council, therefore, urges all affiliated engineering organizations to discuss the major issues in local as well as nation-wide application and asks that they record their conclusions and wishes with the AEC office for staff and committee guidance. Such expressions may be entirely informal, but resolutions are usually more effective. In fact, all actions taken by member organizations or their boards of direction which have a bearing upon public questions, are sought as a background for Council's performance.

Transformations from one system of currents to another are not interpretable in terms of a new graph, that is, Tucker's transformed incidence matrix will not make sense in general. Linear transformations with coefficients rational numbers may be taken as defining new and more complicated circuital paths in the net but do not imply a new graph. All co-ordinate systems are not on a parity, as the use of tensor notation might suggest, for the system that one naturally picks is the simplest.

The diagonal incidence matrix obtained by Tucker associates a potential difference with each branch but does not show what external forces act on the new variables. The proposed viewpoint does both of these things since the potentials with respect to ground of the vertices can be computed from the forces of constraint.

It would thus appear that the application of tensor analysis to the theory of electrical machines and circuits is still obscure.

Yours truly,

W. H. Ingram

New York, N. Y.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. Electrical Engineering will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Tensor Analysis in Electrical Engineering

To the Editor:

In a recent address delivered October 30, 1937, before the American Mathematical Society entitled "The Application of Tensor Analysis to Problems of Electrical Engineering," Professor D. J. Struik finds certain aspects of circuit theory to be at variance with what I have found them to be in my discussion of "tensors" in Electrical Engineering for May 1937, page 615. It seems desirable, therefore, to support a statement there made by me with a more detailed argument. The statement in question was to the effect that no substitution of one set of variables (currents) for another will carry one electrical net over into another.

Professor Struik came to the opposite conclusion and stated that, in particular, a rather simple transformation of the variables mentioned carries a delta connection over into a star connection. I have been unable to verify the example given and believe such transformations do not exist.

It is true that the imposition of Kirchhoff constraints on a previously unconstrained system can be interpreted as a net-to-net transformation (the first net being thought of as n separate loops, the second being the connected system) but net-to-net transformations of a more general kind are not thereby implied. The existence of this apparent net-to-net transformation is quite exceptional and can be explained when a complete correspondence is set up between the purely dynamical aspect of the system and the network graph. This I have done in a paper to be found in abstract form in the November number of the *Bulletin* of the American Mathematical Society and which may be summarized as follows.

Terminology used here will be that of Foster (AIEE Trans., volume 51, 1932, page 309) and Tucker (Electrical Engineering, volume 56, 1937, page 619). As is well known, a vertex corresponds to a constraint; but the rank of the incidence matrix being one less than the number of vertices, one vertex always represents a redundant constraint. By specializing one vertex and making it a *ground-point*, a one-to-one correspondence between the remaining vertices and the independent constraints becomes possible.

Every net implies its *extended graph* formed when all (independent) vertices are connected to the ground-point by *Lagrangean connections* with which are associated the forces of constraint in the same way that the external forces are associated with the various branches of the net proper.

The extended graph has $n + c$ branches (that is, line segments) where c is the number of constraints. Hence exactly n independent circuits exist and these can be so chosen that each circuit lies outside the net proper except, in each case, for one segment in, and characterizing, each circuit. Hence we can say, with the extended graph in mind, that all branch currents are circuital.

Graphical Solution of Impedances in Parallel

To the Editor:

In the October 1937 number of Electrical Engineering (page 1327) I notice that E. C. Goodale gives a graphical method of finding the impedance of two similar impedances in parallel. This method is limited

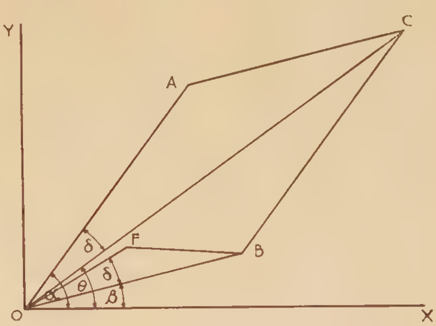


Figure 1

to impedances which can be designated by vectors having the same angle. The following is a method whereby the impedance of any two impedances in parallel may be solved graphically.

Let $A\angle\alpha$ and $B\angle\beta$ be the vector representation of any two impedances.

Draw OA and OB representing $A\angle\alpha$ and $B\angle\beta$ respectively, that is, the length of OA represents to a suitable scale the magnitudes of the vector $A\angle\alpha$ and the $\angle AOX = \angle\alpha$ and $\angle BOX = \angle\beta$. See figure 1.

Complete the parallelogram giving OC = resultant of OA and OB in series.

Upon the base OB construct the triangle OFB similar to triangle OAC.

Then $\angle FOB = \angle AOC$ and $\angle FBO = \angle ACO$.

Then vector OF represents in magnitude

and angle the impedance of $A\angle\alpha$ and $B\angle\beta$ in parallel.

Proof

The impedance of $A\angle\alpha$ and $B\angle\beta$ in parallel

is equal to $\dfrac{A\angle\alpha \; B\angle\beta}{A\angle\alpha + B\angle\beta}$

$$= \frac{OA.OB}{OC} \angle\alpha + B - \theta = R$$

Now $\dfrac{OF}{OA} = \dfrac{OB}{OC}$

Hence $OF = \dfrac{OA.OB}{OC}$ which is the magnitude of R

Now angle of $OF = \angle B + \angle\delta$
and $\angle\theta = \angle\alpha - \angle\beta$

Hence angle of $R = \angle\alpha + B - \alpha + \delta = \angle\beta + \delta$ which is the angle of OF

Hence OF represents the impedance of $A\angle\alpha$ and $B\angle\beta$ in parallel. It can be shown that the vectors can be in any quadrant.

Yours sincerely,
John L. Clarke (A'17, M'30)

Transmission Engineer, Bell Telephone Company of Canada, Montreal

Registration of Engineers

To the Editor:

At the last meeting of the AIEE Worcester Section, our honorable and much respected chairman asked for an expression of opinion on the current vogue of compelling, by law, all engineers to register, that seems to be sweeping the country. He stated that the national organization wanted to know what we thought about it. It was immediately apparent that we had no "thoughts," as we knew practically nothing about its operation. But until we know more about how it operates, we were against it.

The question was raised as to why our national organization has not kept us informed as to what was going on. Electrical Engineering has the necessary contacts throughout the country through which to solicit and secure factual data concerning the operation of such laws in the states where they are in force.

We are told by outsiders that compulsory registration will raise the standards of engineering ethics. Will exposing one's engineering training to microscopic examination by a board of politicians, engineering or otherwise, elevate these lowly ethics? It is my humble opinion that the exact contrary will be true. The whole business will immediately degenerate to a political racket. I venture the guess that in the states where engineers are required to register, be they electrical, civil, architectural, or mechanical, their profession actually has suffered through the law. I can see much embarrassment to competent engineers of long standing when confronted with the examination problem. What nice fat political jobs can be built up around the law? Why not force engineers into the CIO and call it O.K.?

Let's have a little open discussion of this entire mess. It may be too late to do much about it, but it does seem that if real unsavory conditions have developed, a backfire aimed at removing the law from the books can be started and fanned into a real blaze. Surely, the men who have been forced to go over the hurdles in securing registration as engineers know what it means. They also know just what "good" or "harm" is coming from it. They will be doing a brotherly act if they will tell us their story.

Yours very truly,
Louis S. Leavitt (A'24, M'28)

Assistant to Vice-President and General Manager, Worcester Electric Light Company, Worcester, Mass.

Capacitor Motors With Deep-Slot Rotors

To the Editor:

From time to time the question of the advantages of deep-slot and double squirrel-cage rotors with capacitor-start induction motors has been discussed in the technical press, but some disagreement seems to exist in regard to the practicality of such application and the results to be expected. To remove this question from the field of conjecture and to show the advantages and disadvantages of deep-slot designs was the object of the investigation described in this letter.

Characteristics are obtained by calculation. Although these are calculations unverified by tests, the skin effect of deep bars is determined by a process suggested by Punga and Raydt,[3] and which has been found to be reliable in practice.

In general, the advantages to be expected in deep-slot rotor designs for capacitor motors are a reduction of starting current per unit of starting torque and the maintenance of a given starting torque with a smaller capacitor. A limited increase in starting torque can be obtained by an increase in rotor-bar resistance. Yet if this resistance is increased too greatly it will result in less favorable running characteristics; that is, increased rotor losses with increased temperature rise and high full-load slip may accompany too large a value of rotor resistance.

It would seem then that a large value of rotor resistance at start and a smaller value for ordinary running operation would be a highly desirable characteristic. Skin effect in deep bars, to increase the apparent rotor bar resistance at starting, and to reduce it under speed, would help bring about this desirable end. Just how much advantage may be expected to accrue from such construction will be made clear by the analyses described here.

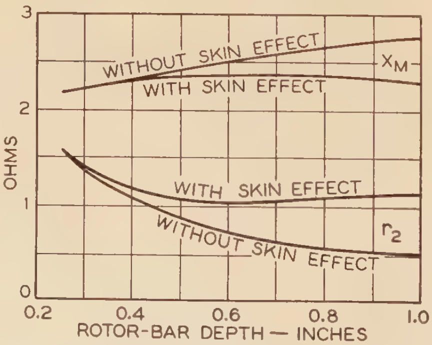


Figure 1. Effect of bar depth on leakage reactance and rotor resistance, with and without skin effect

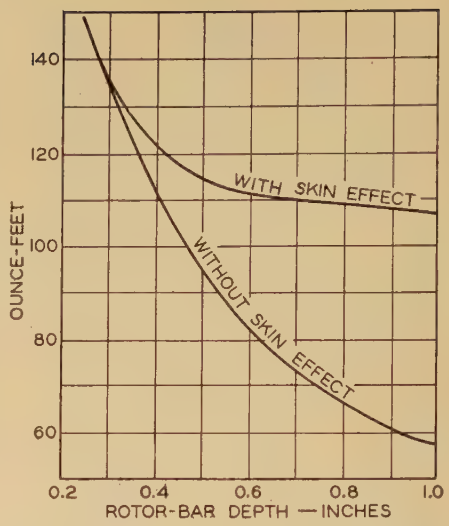


Figure 2. Effect of bar depth on starting torque, with and without skin effect (340 microfarads)

Considering the number of variables with which one may deal in attempting such an investigation, it seemed most advantageous to use the following procedure: A single-phase induction motor of medium size ($^3/_4$ horsepower) and normal design was selected as the basis for an example. Because of rotor diameter limitations smaller machines were rejected as being unsuitable for an extensive change in bar depth. The rotor bars were assumed to increase progressively in depths of 0.25, 0.5, 0.75 and 1.0 inch. For each bar depth, the slot constant and hence the rotor leakage reactance varied. Also for each depth, the value of rotor resistance becomes less because of the increased bar section. Yet with each increase in depth, the skin effect at starting increases, and the resistance under this condition fails to fall off as rapidly as the physical dimensions would imply. This progressive change is

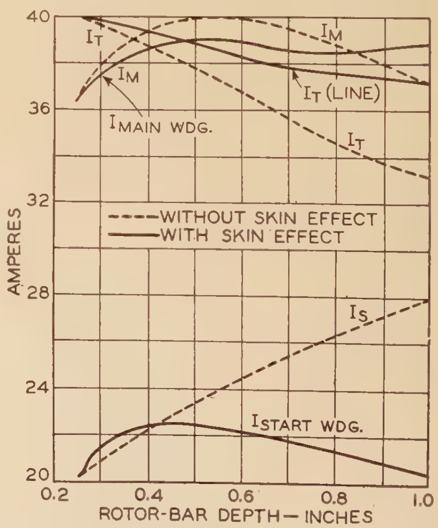


Figure 3. Effect of rotor bar depth on line currents and their components

indicated in figure 1 for both rotor resistance and total leakage reactance. It will be noted that on the smallest depth used (0.25 inch) skin effect at 60 cycles was negligible.

With the machine constants known for each of the five values of bar depth assumed, the starting torque was calculated using the same value of capacitance (340 microfarads) in each case. Starting torque was also calculated for those machine constants which would have resulted if skin effect were neglected. These results are shown in figure 2. The increased starting torque available because of the increased resistance and the decreased leakage reactance, is clearly discernible.

Starting currents, in the main and start windings, and the resulting line currents are indicated in figure 3. If the rotor bars had had no skin effect, the constants would be such as to yield starting currents indicated by the dotted lines. Comparatively little effect is noticed on the main winding current; but in the start-winding circuit, any increase in rotor resistance has a relatively larger effect on limiting the current.

Reduced line currents are obtained in capacitor motors, on starting, because the current in the main winding has a lagging component, and the current in the start winding has a leading component. To take fullest advantage of this it is necessary that the lagging component of the main winding current be relatively large with respect to its in-phase portion. Deep rotor bars are unfavorable for this reason, since skin effect decreases the reactance component of the main winding current. This shows up in unfavorably large line current I_T, larger with skin effect than without.

Another way of considering this same phenomenon is the use of the ratio of line current to the arithmetic sum of the currents in the main and the start windings. The lower this ratio is, the greater is the advantage that has been obtained from the use of a condenser in yielding smaller line currents. This ratio is plotted in figure 4, and it will be noted that it is consistently smaller for the decreased values of rotor resistance (that is, without skin effect). From figure 3, the locked current with skin effect becomes relatively higher as the rotor-slot depth increases, but when this is referred to an "ounce-feet per ampere versus-slot-depth" basis, the net result is still an appreciable increase of starting torque per ampere of line current. This is shown in figure 5.

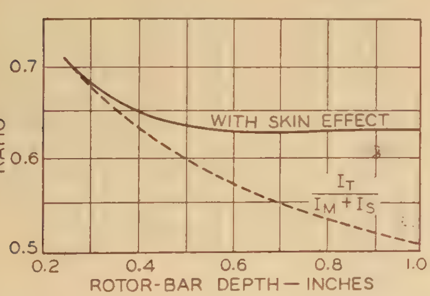


Figure 4. Ratio of line currents to arithmetic sum of main and start currents

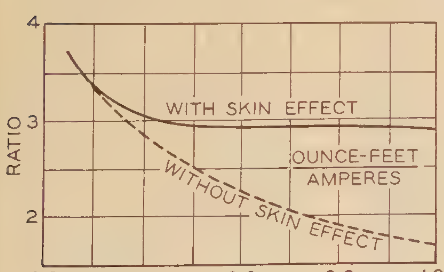


Figure 5. Ounce-feet per ampere versus bar depth, with and without skin effect

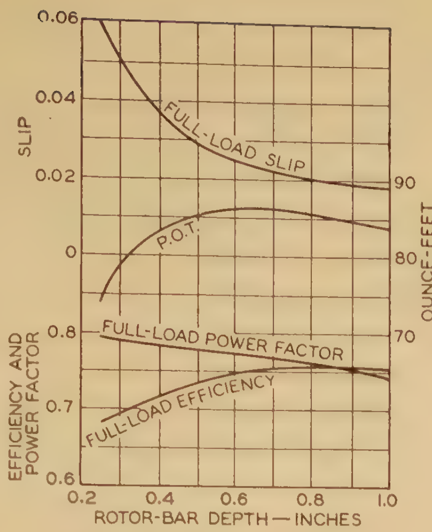


Figure 6. Full-load performance

Any starting characteristic described, such as favorable starting torque, or starting current, or their ratio, can be obtained by using outright the correct value of rotor resistance and rotor tooth shape, with no regard to skin effect. Yet if high rotor resistances must be used, the disadvantage will show up, not so much in starting, but in the running performance. Hence any final advantages must be judged in part by the characteristics of the motor when running. Accordingly the full-load performance (with capacitor winding disconnected) was calculated for each value of rotor-bar depth. Results are indicated in figure 6. Calculations were made by the cross-field theory, outlined by the writers.[1] By this theory no skin effect is considered during operation at low slips. Analysis by the revolving-field theory[2] might yield slightly different results if the change in rotor leakage reactance and resistance to the forward and backward fields were taken into account. For the purposes of this paper the effect is believed to be negligible.

Examination of the entire series of curves shows that there is no "best" depth of bar or amount of skin effect. Increased bar depth decreases the starting torque per ampere and points to conservatism in depth slot design. Increase in efficiency and decrease in full-load slip make small gains after the first few steps. This would imply that extreme depth of bar was desirable only if a very minimum of slip, and the greatest possible efficiency at full load, were of great importance in the design. Improved pull-out torque is also noted by conservancy in bar depth, although a comparatively rapid initial gain is observed.

If a high starting torque per ampere with no restrictions on full load slip and pull-out torque are desired, then there is no need for the deep-bar rotor. The use of deep bars and the degree to which such depth should be carried depends, in the final analysis, upon the relative importance of the various performance items on any individual application.

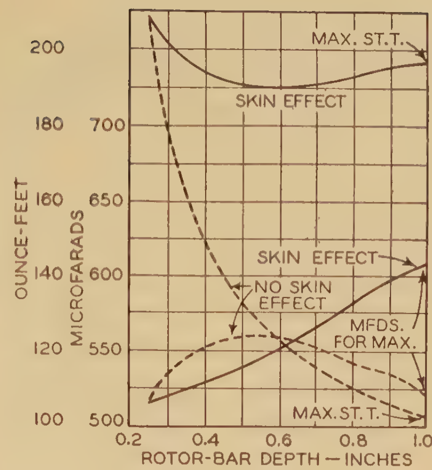


Figure 7. Maximum torque obtainable with each design, with and without skin effect

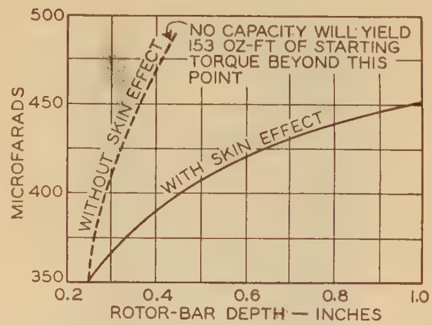


Figure 8. Capacitances required to produce 153 ounce-feet of starting torque, with and without skin effect

The motor used for investigation is rated at $^3/_4$ horsepower, 4 poles, 60 cycles, 110 volts, and the important physical dimensions are:

Diameter of rotor: 4.593 inches
Length of air gap: 0.016 inch
Stacking width: 2.75 inches
Stator slots: 36
Rotor slots: 39
Rotor-bar width: 0.109 inch
Bar depth: variable

References

1. Single-Phase Induction-Motor Performance, A. F. Puchstein and T. C. Lloyd. Electrical Engineering, volume 56, October 1937, pages 1277–84.

2. The Revolving-Field Theory of the Capacitor Motor, Wayne J. Morrill. AIEE Transactions, volume 48, 1929, pages 614–29.

3. Modern Polyphase Induction Motors (a book), F. Punga and O. Raydt. Translated from the German by H. M. Hobart. Pitman Publishing Corporation, New York, N. Y.

Very truly yours,

A. F. Puchstein (A'20, M'27)
Chief Engineer
T. C. Lloyd (A'31)
Development Engineer
Robbins & Myers, Inc.,
Springfield, Ohio

Personal Items

Gano Dunn (A'91, M'94, F'12, past-president, Life Member) president of the J. G. White Engineering Corporation, New York, N. Y., has been awarded the AIEE Edison Medal for 1937 "for distinguished contributions in extending the science and art of electrical engineering, in the development of great engineering works, and for inspiring leadership in the profession." Mr. Dunn was born October 18, 1870, and was graduated from the College of the City of New York in 1889 with the degree of bachelor of science; he received also the degree of master of science from that institution in 1897. Later he received the degree of electrical engineer (1891) and the honorary degree of master of science (1914) from Columbia University. He began his professional career in 1886, in the services of the Western Union Telegraph Company, where he remained five years. He then entered the employ of the Crocker-Wheeler Company at Ampere, N. J., and from 1898 until 1911 was vice-president and chief engineer of that company. In 1911 he was elected vice-president in charge of engineering and construction of J. G. White and Company, and when the J. G. White Engineering Company was organized to take over the engineering and construction work of the parent company Mr. Dunn was made president, which position he still holds. During his period of service with the Crocker-Wheeler Company, Mr. Dunn was granted many patents on generators, motors, rheostats, switches, and on systems of operation, control, and regulation. Since he has been associated with the J. G. White Engineering Company he has been responsible for the design, construction, and operation of many public utility properties, including hydroelectric systems, central lighting and power stations, electric and steam railways, and other services throughout the world. During the World War he was a member of the War Department Nitrate Commission from 1916 until 1918, and was chairman and disbursing officer of a special committee of the State, War, and Navy Departments on submarine cables in 1918. He was also a member of the engineering committee of the Council of National Defence. He was appointed by the president of the United States to the Science Advisory Board, and has been a member since the beginning of the Business Advisory Council for the Department of Commerce. In 1935 he became president of Cooper Union for the Advancement of Science and Art; he is also a trustee of Barnard College and a former trustee of Columbia University. Mr. Dunn is the author of numerous papers on engineering subjects. He has served the Institute on 12 of its committees and has been the Institute's representative on 9 other bodies. He served as a manager of the AIEE 1897–1900 and 1902–05; as vice-president, 1900–02 and 1905–07; and president, 1911–12. From 1900 until 1902 Mr. Dunn was president of the New York Electrical Society. He was president of the United Engineering Societies from 1913 to 1916; of the John Fritz Medal Board of Award in 1914. He was the first chairman of Engineering Foundation (1915–16); and vice-chairman of the National Research Council during 1917, afterward becoming chairman. He was secretary of electric lighting and distribution for the International Electrical Congress at St. Louis, in 1904, and vice-president of the International Congress at Turin in 1911. He was official delegate of the United States Government to the Second Pan-American Scientific Congress in Washington in 1915, and the third Pan-American Commercial Conference in Washington in 1927. He is honorary vice-president of the Pan American Society. Mr. Dunn is honorary secretary for the United States of the Institution of Electrical Engineers (Great Britain), and is a Fellow of the Royal Microscopical Society of London, the Institute of Radio Engineers, New York Academy of Sciences, and the American Association for the Advancement of Science. He is honorary member of the Association of Iron and Steel Engineers, and a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, Franklin Institute, Illuminating Engineering Society, Optical Society of America, National Academy of Sciences, American Philosophical Society, American Academy of Arts and Sciences, Phi Beta Kappa, and others.

GANO DUNN

H. E. Ives (F'29) electro-optical research engineer, Bell Telephone Laboratories, Incorporated, New York, N. Y., has received the Frederic Ives Medal of the Optical Society of America for distinguished work in optics. The medal was established in honor of Doctor Ives' father, a brilliant investigator in optics and a pioneer in color photography and photoengraving. Doctor Ives was born July 31, 1882, at Philadelphia, Pa., and received the degrees of bachelor of science (1905) and doctor of philosophy (1908) from the University of Pennsylvania and The Johns Hopkins University respectively. He received the honorary degree of doctor of science from Dartmouth College (1928), Yale University (1928), and the University of Pennsylvania (1929). Following his graduation in 1908 he was employed in the National Bureau of Standards for one year before becoming a physicist in the research laboratories of the National Electric Lamp Association. In 1912, Doctor Ives became a physicist for the United Gas Improvement Company, where he remained until he received a commission in the United States Army during the World War. He has been engaged in research work for the Bell Telephone Laboratories since 1919. He is the author of many scientific and technical papers and has received Longstreth Medals from the Franklin Institute for work in color photography, "artificial daylight," and studies of the Welsbach mantle. In 1927 he received the John Scott Medal, awarded annually by the City of Philadelphia, for contributions to electrical telephotography and television. Doctor Ives is a past-president of the Optical Society of America, a past vice-president of the Illuminating Engineering Society, and a member of the American Association for the Advancement of Science, American Philosophical Society, American Physical Society, Franklin Institute, Phi Beta Kappa, Sigma Xi, and many other honorary and scientific organizations in the United States and in Europe.

G. W. Patterson (A'37) president of Patterson Electric Limited, Toronto, Ont., Canada recently received the McGraw medal of the National Electrical Contractors Association "for outstanding contributions to the contracting branch of the electrical industry." Mr. Patterson was born November 29, 1896, at Toronto, and received his formal technical education by attending the Toronto Technical School and through the International Correspondence School. He entered the electrical contracting business in 1912. From 1916 until 1920 he served in the Canadian army, and following the World War established his own electrical engineering and contracting business under the name of Patterson Electric Limited. Mr. Patterson has been president of the Ontario Electrical Contractors Association, the Electric Service League of Toronto, and the Electrical Estimators Association, and has been active in committee work of the National Electrical Contractors Association. He is a member of the Illuminating Engineering Society.

H. L. Doherty (A'98, F'13, member for life) president of Cities Service Company, New York, N. Y., has been awarded the Anthony F. Lucas medal "for distinguished achievement in improving the technique and practice of finding and producing petroleum." The medal is awarded annually by the American Institute of Mining and Metallurgical Engineers in memory of Captain Anthony F. Lucas, Texas oil pioneer. Born May 15, 1870, in Boone County, Ind., Colonel Doherty never received a formal technical education but received the honorary degrees of doctor of engineering from Lehigh University and doctor of laws from Temple University. He started his career as an office boy in the

Columbus Gas Company at the age of 12, advancing through various positions until eventually he became assistant general manager of that company. In 1896 Colonel Doherty became general manager and engineer of the Madison (Wis.) Gas and Electric Company, and subsequently held similar positions with other public utility organizations until 1905, when he founded and became manager of Henry L. Doherty and Company, an organization of bankers and operators of public utility corporations. He organized the Cities Service Company in 1910, and has been the only president of that organization. He received the first Beill Gold Medal of the American Gas Light Association in 1898, and in 1930 was awarded the Walton Clark Medal of the Franklin Institute "in consideration of his outstanding and valuable work in development of the manufactured gas industry." Colonel Doherty is a member of the Association for the Advancement of Science, American Society of Heating and Ventilating Engineers, The American Society of Mechanical Engineers, Franklin Institute, and several other societies.

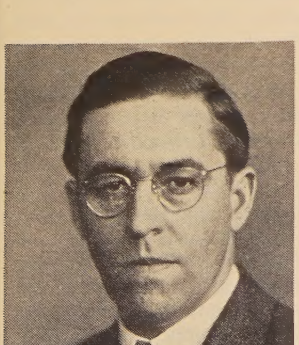
W. L. Upson (A'08, M'20) formerly professor of electrical engineering at Washington University, St. Louis, Mo., recently became affiliated with the Torrington Manufacturing Company, Torrington, Conn., as engineer in charge of research for the company. Mr. Upson was born July 3, 1877, at Cleveland, Ohio, and received the degrees of bachelor of science (1899), electrical engineer (1902), and master of science (1903) at Princeton University. Later he studied in the graduate schools of the University of London (England) and Harvard University. After five years of commercial experience he was appointed to the faculty of Princeton University as an instructor in electrical engineering and physics in 1904. After two years at that institution he went to The Ohio State University as assistant professor of electrical engineering, remaining there until 1910, when he was appointed professor and head of the department of electrical engineering at the University of Vermont. In 1912 Mr. Upson was appointed assistant professor of electrical engineering at Union College; later he became associate professor and remained at that institution until 1920, when he was appointed professor on the electrical engineering faculty of Washington University. Mr. Upson is author of one electrical engineering textbook and co-author of another. He served the Institute as a member of the committee on education, 1921–24 and 1933–36, and is a past-chairman (1917–18) of the AIEE Schenectady Section. He is a member of the Society for the Promotion of Engineering Education, American Association for the Advancement of Science, Sigma Xi, Eta Kappa Nu, and Tau Beta Pi.

F. L. Lawton (A'25, M'36) since 1930 an electrical engineer for the Saguenay Power Company, Ltd., Arvida, Que., Canada, recently became chief engineer of the company. Mr. Lawton was born, December 14, 1900, at London, England and received the degree of bachelor of applied science in electrical engineering at the University of Toronto in 1923. Following his graduation he completed the test course of the General Electric Company, Schenectady, N. Y., and in 1924 was transferred to the general engineering department of that company. In 1925 Mr. Lawton became assistant to the electrical engineer of the Quebec Development Company and during the following year was placed in charge of drafting for a hydroelectric survey; later he was appointed assistant to the superintendent of operation, which position he held until 1930. In that year he became electrical engineer for the Duke-Price Power Company, Ltd., which later became the Saguenay Power Company, Ltd. Mr. Lawton is a member of the Engineering Institute of Canada.

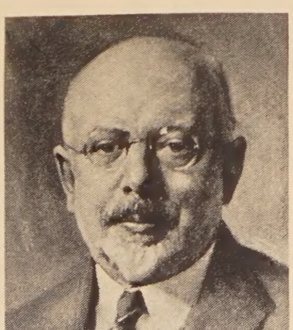
Wilfred Sykes (A'09, F'14) assistant to the president of the Inland Steel Company, Chicago, Ill., has been elected a vice-president and director of the American Institute of Mining and Metallurgical Engineers. Mr. Sykes was born December 9, 1883, at Palmerton, North New Zealand, and received the degree of bachelor of science at the University of Melbourne in 1903. Following his graduation he became an electrical engineer for Knox Schlapp and Company, Melbourne, where he remained until he was employed by Allgemeine Elektricitats Gesellschaft, Berlin, Germany, in 1907. In 1909 he came to the United States and was employed by the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., remaining with that company for 11 years. Following a brief affiliation with the Steel and Tube Company of America, Mr. Sykes joined the engineering staff of the Inland Steel Company in 1923. Mr. Sykes is the author of several papers on the application of electricity in steel mills. He is a member of The American Society of Mechanical Engineers.

L. L. Carter (A'29, M'35) assistant chief engineer, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y., has received honorable mention in the selection by Eta Kappa Nu, honorary electrical engineering society, of America's outstanding young electrical engineer for 1937 (see page 38). Mr. Carter was born June 5, 1903, at Muncie, Ind., and received the degrees of bachelor of science in electrical engineering (1927) and master of science in electrical engineering (1929) at Purdue University, following which he spent three years in the Purdue University Engineering Experiment Station in improving weather-resistant coverings for overhead line wires. Since 1932 Mr. Carter has been associated with the Anaconda Wire and Cable Company, where he has been engaged in detailed operation of the engineering and product development division, including manufacturing, research and developments, customer service, and sales promotion. He is a member of the American Standard Association, American Transit Association, Association of American Railroads, and the American Society for Testing Materials.

C. A. Faust (A'35) in charge of power utility division advertising, Ohio Brass Company, Mansfield, Ohio, has received honorable mention in the selection by Eta Kappa Nu, honorary electrical engineering society, of America's outstanding young electrical engineer for 1937 (see page 38). Mr. Faust is a native (1905) of Bellevue, Iowa, and received the degree of bachelor of science in electrical engineering at Iowa State College in 1927. Following his graduation he became associated with the McGraw-Hill Publishing Company, New York, N. Y., as a student apprentice on the staff of *Electric Railway Journal* (now *Transit Journal*), eventually becoming associate editor of that publication in 1933. In 1936 Mr. Faust transferred his affiliation to the advertising department of the Ohio Brass Company, where he is now in charge of advertising for the power utility department. Mr. Faust has been particu-



F. L. LAWTON



Chester Warner Slack

H. E. IVES

H. L. DOHERTY

G. W. PATTERSON

larly active in Eta Kappa Nu Association, having recently completed two terms as national president.

A. M. Musgrove, Jr. (A'30, M'37) formerly assistant electric distribution engineer for the Public Service Electric and Gas Company, Englewood, N. J., recently was transferred to the Bergen, N. J., division as district distribution engineer. A native (1907) of Gleneld, Md., Mr. Musgrove received the degree of bachelor of engineering at The Johns Hopkins University in 1928 and the degree of master of arts at Columbia University in 1930. Immediately following his graduation in 1928 he entered the employ of the Public Service Electric and Gas Company as a cadet engineer, and after holding several intermediate positions became assistant engineer in 1935.

P. M. Ross (A'34) has been appointed superintendent of the high-voltage laboratory of the Ohio Brass Company. Mr. Ross has been associated with the engineering department of the Barberton (Ohio) division of the company since 1934. Prior to his association with Ohio Brass Company he was with the commercial engineering department of the Frigidaire Corporation. Mr. Ross is an electrical engineering graduate of Purdue University, and is a member of Eta Kappa Nu.

G. W. Swenson (A'19, F'36) professor and head of the department of electrical engineering, Michigan College of Mining and Technology, Houghton, recently was elected president of the North-Midwest section of the Society for the Promotion of Engineering Education for the year 1938. Professor Swenson acted as vice-president of the section during 1937.

P. S. Millar (A'03, M'13) president of the Electrical Testing Laboratories, New York, N. Y., has been elected to serve as president during 1938 of the newly formed American Council of Commercial Laboratories. Mr. Millar is a member of the Institute's committee on the production and application of light.

Robert Triplett (A'32) formerly a receiving engineer at Point Reyes receiving station, RCA Communications, Inc., Inverness, Calif., recently became an assistant radio engineer for the United States Department of Commerce, Bureau of Air Commerce, Salt Lake City, Utah.

R. G. Lockett (M'37) formerly supervising engineer for Cutler-Hammer, Inc., Milwaukee, Wis., has become application engineer in the sales department of the I-T-E Circuit Breaker Company, Philadelphia, Pa.

O. G. C. Dahl (A'22, F'33) has resigned his position as professor of electric power transmission at Massachusetts Institute of Technology, to become an engineer for the consulting engineering firm of Jackson and Moreland, Boston, Mass.

E. R. Heacock (A'33) who has been a merchandise salesman for the Central Illinois Public Service Company, Mattoon, has become a group superintendent for that company.

Agustus Lehrkind (A'37) research engineer for the Burgess Battery Company, Madison, Wis., has been transferred to the Chicago (Ill.) offices of that company, where he will be engaged in the acoustic division.

H. H. Robison (A'34) who has been an electrical engineer for the Dallas Power and Light Co., Dallas, Texas, now is associated with the Texas Power and Light Company, Dallas.

C. G. Wallis (A'26) works engineer, Westinghouse Electric Elevator Company, Chicago, Illinois, has been transferred to the Jersey City (N. J.) works of that company in a similar capacity.

D. J. Corrigan (A'34) formerly a rodman for the Colorado Fuel and Iron Company, Sunrise, Wyo., now is employed by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

B. A. Hultberg (A'31) formerly a radio engineer for the Crosley Radio Corporation, Cincinnati, Ohio, now is employed in the engineering department of General Household Utilities Company, Chicago, Ill.

W. R. Gilsdorf (A'36) formerly a sales engineer for the National Theatre Supply Company, Cleveland, Ohio now is employed by the Spaulding Fibre Company, Cleveland.

W. A. Thomas (A'32) formerly assistant professor of electrical engineering at Antioch College, Yellow Springs, Ohio, recently became a member of the electrical engineering faculty of Iowa State College, Ames.

W. A. Uline (A'30) design engineer for the Scintilla Magneto Company, recently became associated with the engineering department of the New York Power and Light Corporation, Albany.

P. B. Garrett (A'24, M'30) engineering supervisor, Westinghouse Electric & Manufacturing Company, San Francisco, Calif., has been transferred to the Salt Lake City (Utah) offices of that company.

R. U. Muffley (M'23) commercial manager of the Puget Sound Power and Light Company, Seattle, Wash., recently was elected president of the Electric Club of Washington.

C. H. Bunch (A'16, M'32) sales manager, Acme Electric, Cleveland, Ohio, has been transferred to the newly established general offices of that company at Cuba, N. Y.

J. M. Barr, Jr. (A'37) recently became a junior engineer for the Carrier Corporation, Dallas, Texas.

M. P. Smith (A'32) engineer for the General Radio Company, New York, N. Y., has been transferred to the Los Angeles (Calif.) offices of that company.

A. U. Houle (A'27) has become a demonstrator in electrical engineering at the University of Toronto, Toronto, Ont., Canada.

J. P. May (A'30, M'36) central station department, General Electric Company, Pittsfield, Mass., has been transferred to the Atlanta (Ga.) offices of that company.

F. R. Lawson (A'34) recently joined the engineering department of the Pacific Gas and Electric Company, San Francisco, Calif.

J. L. Bronstein (A'36) now is employed by the Wisconsin Rural Electric Co-operative Association as junior electrical engineer.

E. A. Shultz (A'32) recently became affiliated with the Illinois-Iowa Power Company, Champaign, Illinois, as an electrical engineer.

Obituary

Edward Leamington Nichols (A'87, M'87, member for life) professor emeritus of physics, Cornell University, Ithaca, N. Y., died November 10, 1937. Professor Nichols was born September 14, 1854, and received the degree of bachelor of science at Cornell University in 1875, following which he went to Germany to continue his studies in physics. In 1879 he received the degree of doctor of philosophy at Göttingen, and in 1906 the University of Pennsylvania conferred upon him the honorary degree of doctor of laws. Upon completion of his studies in Germany, Doctor Nichols returned to the United States as a fellow at The Johns Hopkins University. In 1880 he joined the staff of Thomas A. Edison at Menlo Park, N. J., but after one year received an appointment as professor of physics at the Central University of Kentucky. In 1883 Doctor Nichols was appointed to the faculty of the University of Kansas, and in 1887 became professor of physics at Cornell University. Doctor Nichols was founder of *Physical Review* and was editor of that publication from 1893 until 1912. He was author or co-author of several textbooks and many papers and articles on scientific subjects. He was past-president of the American Association for the Advancement of Science and the American Physical Society, and was a member of the American Academy of Arts and Sciences, American Philosophical Society, Illuminating Engineering Society, and several other scientific societies.

Philip Bell Woodworth (A'00, member for life) counsellor at law in the firm of Rummler, Rummler, and Woodworth, Chicago, Ill., died in June 1937, according to word just received at Institute headquarters. Mr. Woodworth was born October 19, 1865, at Auburn, N. Y., and was graduated from the Michigan Agricultural College in 1886 with the degree of bachelor of science, following which he was employed by the State of Michigan as a civil engineer. He later enrolled in the engineering school of Cornell University and was graduated with the degree of mechanical engineer. After a brief association with the Brush Electrical Com-

pany, Mr. Woodworth went to Berlin, Germany, to pursue advanced studies in physics and electricity. In 1892 he returned to the United States and was placed in charge of the departments of physics and electrical engineering at the Michigan Agricultural College, where he remained until 1899 before being appointed to the electrical engineering faculty of Lewis Institute, Chicago. Later he became dean and professor of electrical engineering at that institution. During the World War he served as technical and educational advisor to the United States Army, and following the war became president of the Rose Polytechnic Institute, Terre Haute, Ind., where he remained until his retirement in 1925. He then became an engineering attorney in the firm of Rummler, Rummler, and Woodworth.

Charles Phillip Randolph (M'17) vice-president of the Edison General Electric Appliance Company, Inc., Chicago, Ill., died November 30, 1937. Mr. Randolph was born at Austin, Tex., December 30, 1888, and received the degrees of bachelor of arts (1908) and master of arts (1909) at the University of Texas. In 1909 he enrolled in the graduate school of Massachusetts Institute of Technology, and in the following year was appointed a research associate in chemical engineering. During 1911–12 he was an assistant to William Stanley (A'87, M'98, F'13, Edison Medalist '12, past vice-president) in evolving electric heating apparatus for the General Electric Company, Pittsfield, Mass., following which he was placed in charge of experimental work on heating devices and later made managing engineer of the heating device department of that company. When the heating device department of the General Electric Company was consolidated with the Hughes Electric Heating Company and the Hotpoint Company to form the Edison General Electric Appliance Company, Inc., in 1928, Mr. Randolph went to Chicago to become chief engineer of the new company. He became vice-president in charge of engineering in 1937.

Harry Arnold Baker (M'29) professor of physics, John Tarleton Agricultural and Mechanical College, Stephenville, Texas, died October 19, 1937. Professor Baker was born January 20, 1872, at Pittsburgh, Pa., and received the degree of master of science at Trinity University in 1907. In 1913 he received the degree of civil engineer from Reynolds College. In 1909 he was appointed professor of science at Reynolds College and at the same time entered the graduate school of that institution. In 1913 he became professor of physics and chemistry at Randolph College and after two years went to the Wichita Falls (Texas) High School as head of the science department. From 1917 until 1920 Professor Baker held a commission in the United States Army, and following the World War became associate professor of chemistry at John Tarleton Agricultural and Mechanical College. He became professor of physics in 1923. He was a member of the Canadian Institute of Chemistry, Society of American Military Engineers, and American Institute of Mining and Metallurgical Engineers.

David Francis Crawford (A'95, M'09, F'12, member for life) consulting engineer, Pittsburgh, Pa., died March 6, 1937, according to word just received at Institute headquarters. Mr. Crawford was born at Pittsburgh, December 4, 1864, and was educated in private schools and at the Pennsylvania Military Academy. In 1885 he became an apprentice in the machine shop of The Pennsylvania Railroad, and in 1889 was made an inspector in the test department of that company. From 1892 until 1899 Mr. Crawford held various positions with railway and manufacturing companies, and in the latter year was appointed superintendent of motive power on The Pennsylvania Railroad lines west of Pittsburgh. In 1903 he was appointed general superintendent of motive power and remained in that position until 1918, when he became vice-president of the Locomotive Stoker Company, Pittsburgh. Three years later he became president of the Westinghouse Union Battery Company, and held that position until he established his own consulting engineering offices in Pittsburgh in 1928. He was a member of The American Society of Mechanical Engineers.

LeRoy Carlisle Williams (A'15, M'26) chief specification and materials engineer, procurement division, United States Treasury Department, Los Angeles, Calif., died September 19, 1937. Mr. Williams was born January 7, 1894, at Brooklyn, N. Y., and attended the Polytechnic College of Engineering at Oakland, Calif., following which he was employed in the maintenance department of the North Western Pacific Railway Company. In 1913 he was employed in the department of operation and maintenance of the Pacific Gas and Electric Company, San Francisco, where he remained for 9 years before becoming affiliated with the department of public service of the City of Los Angeles. Mr. Williams was appointed manager of the Los Angeles district office of the Pacific Electric Manufacturing Company in 1925, and remained with that company until 1933, when he became a member of the firm of the Coast Engineering and Equipment Company, Los Angeles. He became affiliated with the United States Treasury Department in 1935.

Max A. Berg (A'03) vice-president and secretary of the Electric Service Supplies Company, Chicago, Ill., died in July 1937. Mr. Berg was born December 3, 1869 at Chicago. After holding various positions with several electrical supply companies, he became the secretary of the firm of Porter and Berg, holding that position until 1910, when he became secretary of the Electric Service Supplies Company. Later he was given the additional duties of vice-president of the organizations.

Clifford Whitman Bates (A'08, M'13) technical writer in the advertising department of the Leeds & Northrup Company, Philadelphia, Pa., died December 4, 1937. Mr. Bates was born March 9, 1884, at Cleveland, O., and received the degrees of bachelor of philosophy (1905) and master of science (1908) at Yale University. Following his graduation in 1905 he was appointed to the electrical engineering faculty of Yale University as an instructor and remained at that institution until 1915, when he became an engineer in the meter and installation department of the Philadelphia Electric Company. Later he became research engineer, research assistant to the chief engineer, and technical assistant to the general manager of that company. In 1930 Mr. Bates became associated with the Leeds & Northrup Company, where he remained continuously except for a brief period as assistant associate director of engineering of the Museum of the Franklin Institute.

William Frederick McLaren (A'03, M'30) chief draftsman of the Canadian Westinghouse Company, Ltd., Hamilton, Ont., died August 19, 1937. Mr. McLaren was born at Hamilton, May 21, 1871, and was graduated from Cornell University with the degree of mechanical engineer in 1894. In 1895 he was employed by the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., and after two years with that company he went to Montreal, Que., to become a test engineer for the Royal Electric Company. In 1901 Mr. McLaren returned to the employ of the Westinghouse company at East Pittsburgh, and in 1905 was transferred to the offices of the Canadian Westinghouse Company, where he held the position of chief draftsman for almost 32 years.

William Benjamin Folline (A'19, M'28) electrical engineer, General Electric Company, Dallas, Texas, died November 25, 1937. Mr. Folline was born at Hiawatha, Kans., January 31, 1886, and received his formal training in electrical engineering at Pratt Institute. In 1917 he entered the test course of the General Electric Company, Schenectady, N. Y., and in the following year was transferred to the switchboard engineering department of that company. In 1921 he was transferred to the Dallas, Texas, offices of the General Electric Company, and remained there for almost 17 years.

Robert J. Deneen (A'26) vice-president of the Ohio Brass Company, Chicago, Ill., died December 12, 1937. Mr. Deneen was born August 3, 1881, at Milwaukee, Wis., and was educated at Marquette Academy and Marquette University. Following three years as a sales engineer for the Johns-Manville Company, Mr. Deneen was employed by the Ohio Brass Company and was associated with that organization for 30 years, serving in the capacity of district sales manager in the Chicago area until 1928, when he was appointed vice-president in charge of Middle Western sales.

Joseph A. Hepp (M'30) industrial engineer for the Union Electric Light and Power Company, St. Louis, Mo., died October 21, 1937. Mr. Hepp was born November 13, 1889, at St. Louis, and received the degrees of bachelor of science in chemical engineering (1912), master of science (1914), and

chemical engineer (1920) at Rose Polytechnic Institute. Following his graduation in 1912 he became a chemist with the United Railways Company, St. Louis, and in 1914 he was employed by the Aluminum Ore Company, East St. Louis, Ill. In 1921 Mr. Hepp became affiliated with the Union Electric Light and Power Company as a research engineer; in 1925 he became assistant superintendent of electrical distribution, and later industrial engineer.

EDWARD J. PRATT (A'25) telephone engineer, Bell Telephone Laboratories, Incorporated, New York, N. Y., died December 12, 1937. Mr. Pratt was born March 11, 1887 at Glendale, S. D., and received the degree of mechanical engineer in electrical engineering at The Ohio State University in 1911. Immediately following his graduation he became associated with the Western Electric Company at Chicago, Ill., as a designing telephone engineer. Three years later Mr. Pratt was transferred to the New York offices of the Western Electric Company, and in 1925 he was transferred to the technical staff of the Bell Telephone Laboratories.

Membership

Recommended for Transfer

The board of examiners, at its meeting on December 16, 1937, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Hill, Leland H., engineer in charge, transformer division, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Oboukhoff, N. M., research professor of electrical engineering and professor of mathematical physics, Oklahoma Agricultural and Mechanical College, Stillwater, Okla.

2 to Grade of Fellow

To Grade of Member

Bechlem, Alfred W., designing and drafting, Eastman Kodak Company, Rochester, N. Y.
Bogan, L. B., engineer, American Telephone and Telegraph Company, 195 Broadway, New York, N. Y.
Brackett, C. H., electrical engineer, Union Carbide Company, Niagara Falls, N. Y.
Butler, J. W., central station engineer, General Electric Company, Schenectady, N. Y.
Nixon, G. M., engineer, National Broadcasting Company, New York, N. Y.
Poage, F. C., electrical engineer, Ebasco Services, Inc., New York, N. Y.
Rankin, R. H., Eastman Kodak Company, Rochester, N. Y.

7 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before January 31, 1938, or March 31, 1938, if the applicant resides outside of the United States or Canada.

Ankrum, P. D., Indiana Technical College, Ft. Wayne, Ind.
Averitt, R. A., General Electric Company, Schenectady, N. Y.
Baldwin, C. H., American Steel & Wire Company, Kansas City, Mo.
Bennett, R. H, U. S. S. *Concord*, San Diego, Calif.
Bradford, R. C., Southern New England Telephone Company, New Haven, Conn.
Breth, J. E., Consolidation Coal Company, Inc., Fairmont, W. Va.
Bruce, D., Sangamo Company, Ltd., Toronto, Ont., Canada.
Chandler, R. B. (Member), Public Utilities Commission, Port Arthur, Canada.
Conrad, T. W., Graybar Electric Company, Tulsa, Okla.
Criddle, F. P., General Electric Company, Schenectady, N. Y.
Croft, C., Railway and Industrial Engineering Company, Los Angeles, Calif.
Darcey, J. F., Capital Transit Company, Washington, D. C.
Drew, G. G., Westinghouse Electric & Manufacturing Company, Newark, N. J.
Fox, G. W., Emerson Electric Manufacturing Company, St. Louis, Mo.
Fukuda, F. M., 463 Twenty-fourth Street, Oakland, Calif.
Gardberg, J., Cutler-Hammer, Inc., New Orleans, La.
Group, J. C. (Member), Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
Hammerschmidt, G. L., Northern Indiana Public Service Company, Hammond, Ind.
Hagler, J. M., Southwestern Bell Telephone Company, Dallas, Texas.
Henry, T., Jr., Canadian General Electric Company, Toronto, Ont., Canada.
Howell, L. T., The Chesapeake and Potomac Telephone Company, Baltimore, Md.
Howell, W. D., Pacific Gas and Electric Company, Oakland, Calif.
Hubbard, C. R. (Member), Garlock Packing Company, Palmyra, N. Y.
Ingram, S. B. (Member), Bell Telephone Laboratories, Incorporated, New York, N. Y.
Knudsen, K. J. (Member), Hickok Electrical Instrument Company, Cleveland, Ohio.
Krachy, A. C., Brance-Krachy Company, Inc., Houston, Texas.
Kranenburg, P. J., General Electric Company, Philadelphia, Pa.
Krause, E. R., Jr., Queens Borough Gas and Electric Company, Far Rockaway, N. Y.
Lapsley, R. P., The Okonite Company, New Orleans, La.
Lehde, P. E., (Member), Electron Engineering Company, New Orleans, La.
Lee, H. R., Bureau of Reclamation, Denver, Colo.
Lefler, C. C., Kuhlman Electric Company, Bay City, Mich.
Lillquist, A. E. (Member), Cutler Hammer, Inc., Milwaukee, Wis.
Logan, E. W., Emerson Electric Manufacturing Company, St. Louis, Mo.
Maxwell, J. P., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
Merritt, M. S., Tennessee Valley Authority, Wilson Dam, Ala.
Miller, G. O. (Member), Phillips Petroleum Company, Bartlesville, Okla.
Moore, H. D. MacL., Sangamo Company, Limited, Toronto, Ont., Canada.
Newman, J. M. (Member), Cutler Hammer, Inc., Milwaukee, Wis.
Oliver, J. McC., (Member), Westinghouse Electric & Manufacturing Company, Birmingham, Ala.
Peregrine, C. A., National Broadcasting Company, Denver, Colo.
Phillips, L. A. (Member), Pennsylvania Power & Light Company, Hazleton, Pa.
Poland, H. O., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
Quinn, R. F., General Electric Company, Pittsfield, Mass.
Ray, W. B., United States Engineer Office, Zoarville, Ohio.
Rhoton, W. O., Delco Remy Corporation, Anderson, Ind.
Roempke, H. F., Indianapolis Power and Light Company, Indianapolis, Ind.
Ross, F. G., General Electric Supply Corporation, Tulsa, Okla.
Snyder, R. H., U. S. Electrical Motors, Inc., Brooklyn, N. Y.
Stevenson, R. E. (Member), Polytechnic College of Engineering, Oakland, Calif.
Stormont, G. I., 601 Water Board Building, Detroit, Michigan.
Taylor, T. A. I. C., Saguenay Power Company, Ltd., Isle Maligne, Que., Canada.
Templeton, E. H., Imperial Irrigation District, Imperial, Calif.
Toepperwein, E. W., Southwestern Bell Telephone Company, Dallas, Texas.
Wetherby, T. C., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
Zemaitis, V. J., RCA Communications, Inc., New York, N. Y.

56 Domestic

Foreign

Alag, S. S. (Member), Mahendra and Sons, Calcutta, India.
Attard, J. (Member), 69 Strada Zecca, Valletta, Malta.
Bhattacharyya, A. B., Tinnevelly Tuticorin Electric Supply Company, Ltd., Tinnevelly, South India.
Kirkwood, I. W. A. (Member), Messrs. A. Reyrolle and Company, Hebburn-on-Tyne, England.
Lambert, G. K., 5 Church Street, Wolverton, Bletchley, Bucks, England.
Sofiano, G. C., The Electric Construction Company, Ltd., Birmingham 3, England.
Stigant, W., Bruce Peebles and Company, Ltd., East Pilton, Edinburgh, Scotland.
Tamai, A., (Member), Piazza Crispi, 3, Milano 103, Italy.

8 Foreign

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, recently are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

MECHANICS. By W. F. Osgood. New York, The Macmillan Company, 1937. 495 pages, diagrs., tables, 9 by 6 inches, cloth, $5.00. Constitutes a co-ordination of mathematical theory with physical principles. The first 9 chapters present elementary mechanics from the physical point of view; the last 6 demonstrate the use of such mathematical tools as Lagrange's and Hamilton's equations in solving physical problems.

DELTA, ESTUARY and LOWER PORTION of the CHANNEL of the COLORADO RIVER 1933 to 1935. By G. Sykes. Washington, D. C., Carnegie Institution of Washington, 1937. 70 pages, illustrations, 10 by 7 inches, paper, $1.25. A study of the lower Colorado River presenting data on the flow, silt deposition, and movement of the river during the periods of time immediately preceding and following the closure of the Boulder dam.

UTILISATION of ELECTRIC ENERGY. By E. O. Taylor. New York, D. Van Nostrand Company, 1937. 342 pages, illustrations, 9 by 6 inches, cloth, $6.00. Aims to cover the whole range of the more usual applications in a single volume and in a manner suitable for a student or an engineer who does not specialize in any branch.

TRANSIENT ELECTRIC CURRENTS. (Electrical Engineering Texts). By. H. H. Skilling. New York and London, McGraw-Hill Book Company, 1937. 349 pages, illustrations, 9 by 6 inches, cloth, $4.50. A presentation of the basic principles of transient phenomena, in which abstract mathematics has been restricted to a minimum. The first 4 chapters cover inductance, capacitors, circuit equations, and the complete single circuit. The addition of chapters 5 and 6 completes a course on the treatment of networks of lumped parameters. Separate chapters take up coupled resonant circuits, circuits with variable parameters, traveling waves, operational methods of analysis, and oscillographs.

TELEVISION ENGINEERING. By J. C. Wilson. London, Sir Isaac Pitman and Sons; New York, Pitman Publishing Corporation, 1937. 492 pages, illustrations, 9 by 6 inches, cloth, $10.00. Presents the essentials of television from an engineering point of view. Various chapters include scanning methods, photosensitivity, light modulation, synchronizing, and certain special methods and equipment.

TELEVISION CYCLOPAEDIA. By A. T. Witts. New York, D. Van Nostrand Company, 1937. 151 pages, diagrs., charts, tables, 9 by 6 inches, leather, $2.25. The work "cyclopaedia" has been applied to this rather small book because it attempts to provide concise knowledge, as distinct from mere definitions. The resulting effect is as if the material in a television textbook were distributed under its alphabetical index headings, making the information more directly available.

SYNTHETIC RUBBER. By W. J. S. Naunton. London and New York, Macmillan Company, 1937. 162 pages, illustrations, 9 by 6 inches, cloth, $2.50. Presents a brief history of the attempts to produce rubber synthetically, and describes the characteristics of the more successful synthetic rubbers, including the technology and applications.

MANUAL on RESEARCH and REPORTS by the Committee on Research of the Amos Tuck School of Administration and Finance, Dartmouth College. New York and London, McGraw-Hill Book Company, 1937. 140 pages, 8 by 5 inches, cloth, $1.25. Describes the preliminary procedure and mechanics of investigating a subject, and on some of the important standards to be observed in presenting the findings. Writers of theses and research reports may find the book helpful.